

## REMOTE SENSING FOR NATURAL HAZARD STUDIES

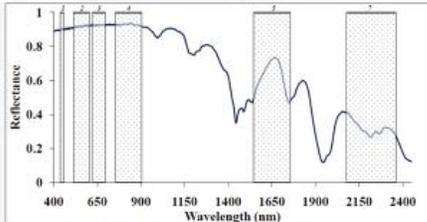
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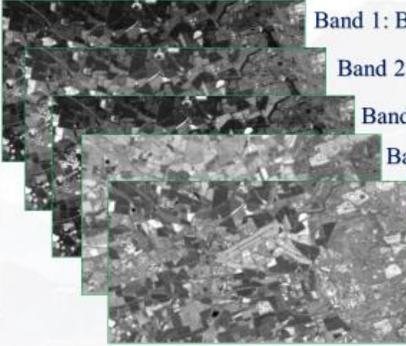
### Lecture 2a: Basics of Remote Sensing -Part A

Hello everyone, today we will continue the lecture on Remote Sensing for Natural Hazard Studies with Lecture 2, which is on the Basics of Remote Sensing. This lecture has been divided into two parts: Basics of Remote Sensing-1 and Basics of Remote Sensing-2. So, you may recall the concepts that I covered in the last lecture, where we discussed how remote sensing images are different from our mobile phone images and how they are different from our DSLR images.

Remotely Sensed Imagesभारतीय प्रौद्योगिकी संस्थान गुवाहाटी  
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Landsat 7 ETM+



- Band 1: Blue Wavelength
- Band 2: Green Wavelength
- Band 3: Red Wavelength
- Band 4: NIR Wavelength
- Band 5: SWIR Wavelength

Formats in which satellite images are stored:

- Band Sequential (BSQ),
- Band Interleave by line (BIL),
- Band Interleave by pixel (BIP).

Remote Sensing for Natural Hazard StudiesDr. R. Bharti

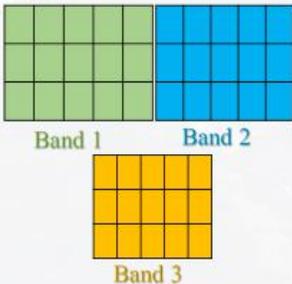
So, you can see this image, which is on the left-hand side of this slide; here, you can find the distribution of the bands in this wavelength region, 400 to 2400 nanometers. So, this is for the Landsat 7 ETM+ sensor. So, you can see it here. The first band is here, the second is here, the third is here, the fourth is here, the fifth is here, and the seventh is here. So, you can see that all these images were generated using the different wavelength ranges. So, for

example, the 7th band is using the wavelength from here to here, and the 5th is using it from here to here. So, it is not uniform. So, that is what we discussed in the last lecture: the spectral resolution that we need to define the starting and ending wavelengths of the image. So, here, using this particular configuration, this particular sensor is capable of generating 6 images. So, here you have 1, 2, 3, 4, 5, and 6. These six images will be different from our mobile camera images. How? Because when we capture images with our mobile phones, we find that we get only RGB combinations. So, that is a color composite in which we are using the red, green, and blue wavelength regions to generate an image. But here, if you see with this configuration, we are able to produce, let's say, 5 images. So, these 5 images are available with us in separate files, right? So, can you just think of how to store these images together? Because here you have 6 bands, here you have 5 bands, some of the sensors will have hundreds of bands, and some of the sensors will have only 10 bands. So, how do you store these images together? Then, you will be able to use them in your further analysis.

DIGITAL IMAGE: Data Formats
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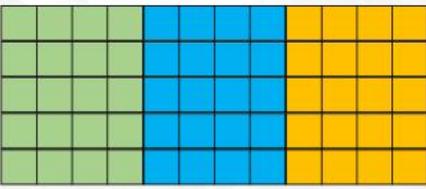
**Band Sequential (BSQ):**

Data for a single band for the entire scene is written in one file (a separate file for each band)



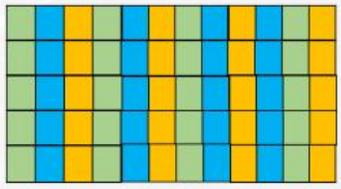
**Band Interleave by line (BIL):**

Data for all the bands are written as line by line on the same file.



**Band Interleave by Pixel (BIP):**

Data for the pixels in all bands are written together.



Band 1

Band 2

Band 3

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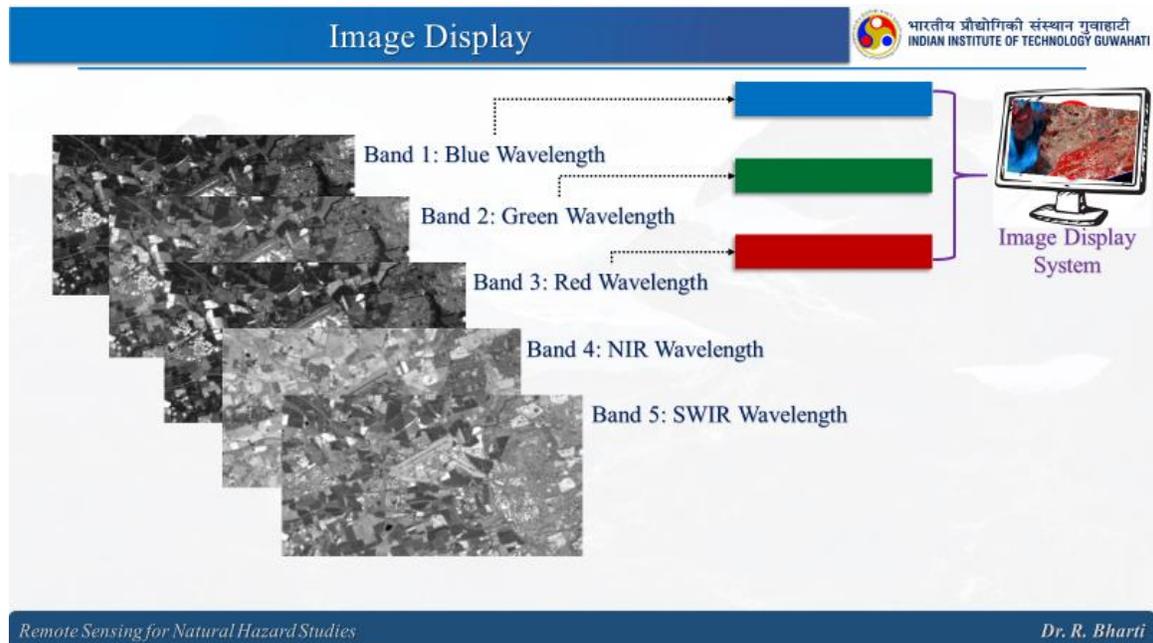
So, this is the data format that we are using in remote sensing. So, band sequential (BSQ), then band interleaved by line, then band interleaved by pixel. So, we will see those three combinations, BIP, BIL, and BSQ, in detail, but here, for the time being, consider that you have only three bands. This is band number 1, band number 2, and band number 3. So, band number 1 is green, band number 2 is blue, and band number 3 is orange. So, you refer to these color codes, and then we will be able to understand. So, when we say that band sequential data for a single band for the entire scene is written in one file. So, what will happen to a separate file for each of the bands, right? So, here you have Band 1, Band 2, and Band 3. Remember, we are using these color combinations correctly. Now comes the BIL band interleave by line; here, data for all the bands are written line by line in the same

file. So, here is the first line of the first band, the first line of the second band, the first line of the third band, then the second line of the first band, the second line of the second band, and the second line of the third band.

Similarly, the third line of the first band, the third line of the second band, and the third line of the third band. So, similarly, we will store these values together in one file. Then comes the band interleaved with pixels. So, data for all the pixels from all the bands is written together. So, how will we store it? First pixel of the first band, first pixel of the second band, first pixel of the third band, then second pixel of the first band, second pixel of the second band, second pixel of the third band. Similarly, we will store these together. So, these are the three basic data formats that we are using in remote sensing to store our satellite images. I hope this concept is clear because our mobile phones or camera photographs are produced in RGB combinations. So, there you are, using only JPEG or TIFF. So, that is very simple, but when you are handling a larger number of images together, which are captured by the same sensor at the same time, then you need to store them together for further analysis; for that, we are using the BIL, BSQ, and BIP data formats. Now, once you have stored them together, how do you display them? Because just now, we discussed that our mobile phone camera directly comes in the combination of RGB. So, when we refer to any image display system, it has three primary colors. blue, green and red and now with our satellite images or the sensors, we are able to generate multiples of images captured at the same time but different in wavelength. Now, when we have a display system and data available to us, we can use this opportunity to change the combination as well. So, we need a minimum of 3 inputs for this to display the data. Now, what we can do is direct this third band to red, the second band to green, and the first band to blue, and here you will get an image, right? When we provide the input from this satellite image, your data sets will be displayed on your display system. Now, this combination is blue to blue, green to green, red to red. This is not mandatory. This is very flexible. Depending on your application and your objective, you can choose any of the bands that will pass through red, blue, or green, right? So that we can see here.

So, here you have a display system; these are the primary colors of your display system, and these are your data sets. So, a minimum of 3 bands is required to provide the input to display your data, right? So, for the display of remotely sensed images, we generally use these three: false color composite and natural color composite. A grayscale images. So, to understand the difference in color composite, you need to. These three-color composites are commonly used in remote sensing. So, we will just understand the color composite. So, if you provide any combination other than the standard one, then it is known as the color composite; even the false color composite is also a color composite, and natural is also a color composite, right? So, to display any satellite image in colors, we need to select image bands corresponding to the red, green, and blue colors of our display system; that is what is explained here. Now, we will see this false-color composite, which is very popular in

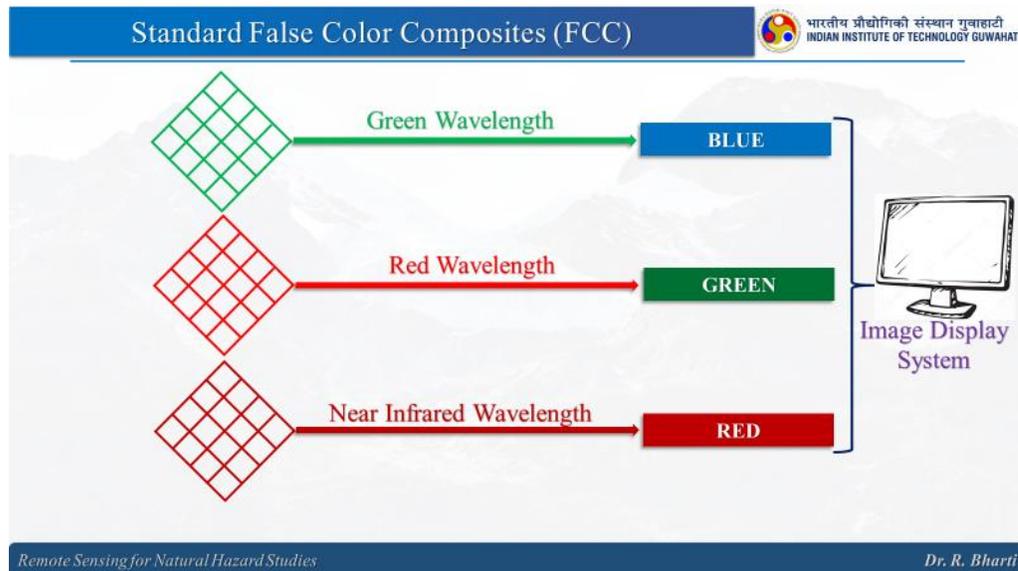
remote sensing. If you refer to any standard published paper, you will find that people have used the standard false color composite to display their study area correctly.



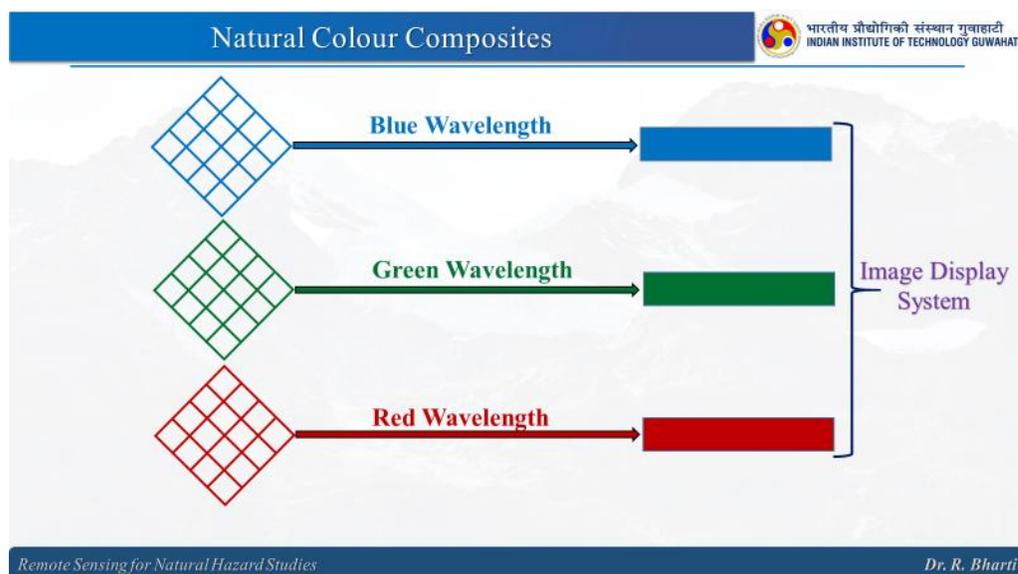
So, this is the display system, and we have three primary colors: blue, green, and red, and we have these combinations. So, we have green, we have red, and we can have one band in infrared. So, if we have this kind of combination, the green will go to blue, red will go to green, and the near-infrared band will be mapped to red. If we have this combination, we will be able to produce this kind of image. Here, you can see this red color. If you remember, in my previous lecture, I mentioned considering red as your vegetation right. So, to understand this, I will just refer to the spectral behavior of vegetation. So, let us say this is the spectrum of vegetation; let us say this is 400 to 2500 nanometers. This is reflectance, right? So, this is the typical vegetation spectrum; now, here you see this is the green region. This is the green region, right? Here, to our eyes, vegetation appears green, which means the green wavelength is reflected by the vegetation, isn't it? Then only this is reaching our eyes, and we are able to see it in green. But if you see red, red is absorbed. So, basically, plants have a special interest in red. But when we go to NIR, we find that this reflected energy is much more than that. This is much more than that. So, since our eyes are capable of seeing only this particular wavelength region, vegetation appears green. But if we had been capable of seeing this particular wavelength region with some other color, then we would have seen the vegetation in this color, right? Since our eyes are not capable of perceiving it, it appears green to us.

Now, you remember that in the NIR wavelength, the vegetation has much higher intensity than in the green wavelength. So, now, what we did is we mapped the near infrared to our

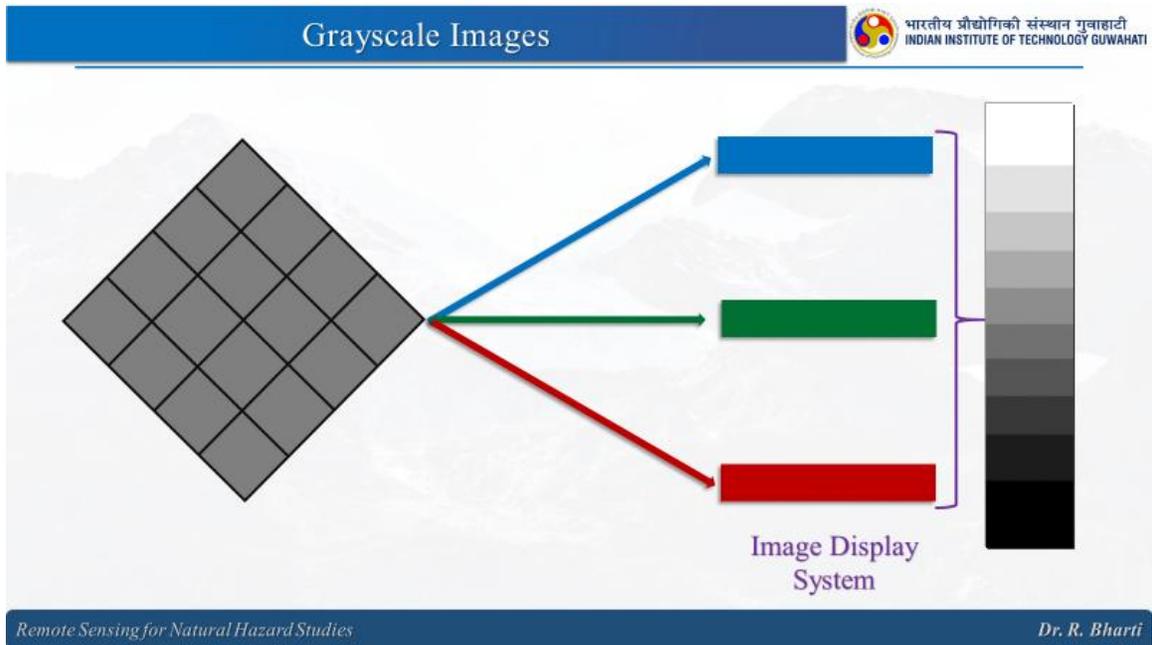
red wavelength. So, near-infrared wavelengths are used in our display system, which is why this red color represents the vegetation. I hope this is clear.



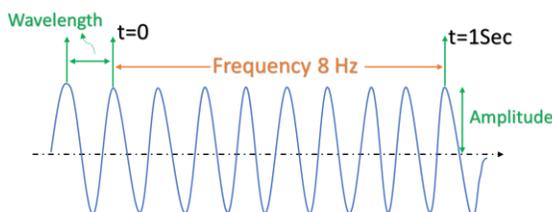
Now, we will talk about the natural-color composite. So, this natural color composite is as good as seeing the objects in the same color; we will try to generate the images. So, the blue wavelength will be mapped to the blue color, green will be mapped to green, and red will be mapped to red. So, if we use this combination, we will call it natural color composite. If we use green to blue, red to green, and near infrared to red, we will call it a standard false color composite. And the images will appear like this. So, here you can see the vegetation will appear in dark green or light green depending on its color; the ocean part appears in blue or maybe dark color depending on the suspended sediment. So, this is the natural color composite.



Now, we also have an image, which is called a panchromatic image, where we have only one image. So, we do not have the option to provide three inputs to our display system, and our display systems are made to display the color composite. So, what will we do with this panchromatic image or any image from any satellite? So, what we will do is have the same configuration, but the same input will go into all three colors, and then we will be able to produce the grayscale image. So, this is the grayscale. So, here white to black will be the range of the colors.

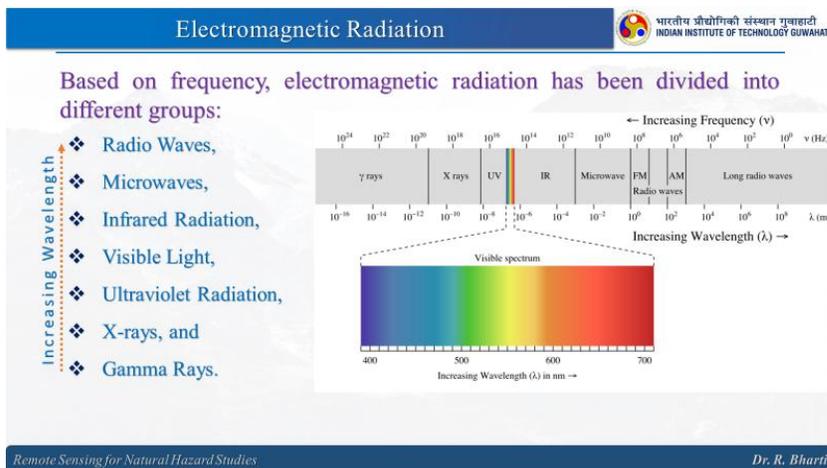


Now, if you remember the basics of remote sensing, where we are using the sun as our source of light and this light is reaching this particular surface, then it is getting reflected, emitted, or backscattered and is being captured by our sensor. And we say that, depending on the characteristic absorption feature, we try to identify the material. So, the material's atomic structure and the chemical composition play a big role in whether a particular wavelength will be absorbed or reflected; it all depends on the material's properties, and once we have that. Then we will be able to identify the material based on one absorption feature or maybe a set of absorption features. So, once we have that, we are able to generate this kind of image.



Frequency, wavelength, and amplitude of a wave

So, before we go into the analysis and other parts of remote sensing, we need to understand the basics of EMR, how it interacts, what the properties of EMR are, and how we refer to those properties in remote sensing, as well as how they are used to establish the standard method to identify the material. So, the electromagnetic radiation has both electric and magnetic fields that are orthogonal to each other, which means perpendicular to each other and also perpendicular to the direction of travel. I hope you remember this basic physics concept. So, here you can see that all of them are perpendicular to one another. So, the first one is that the electric and magnetic fields are both perpendicular to each other and also perpendicular to the direction of travel. So, this will define electromagnetic waves. Now, electromagnetic waves propagate at the speed of light through a vacuum. Now, you must be surprised to know that because of this property, we are able to do satellite measurements from space. Right. Otherwise, if the light is not allowed or it is not capable of traveling through the vacuum, how will we be able to do remote sensing from space, because the atmosphere is limited to a certain extent? Beyond that, we have a space, and light is capable of traveling throughout the atmosphere and through space to our sensor at the speed of light. So, electromagnetic energy is a mixture of waves with different frequencies. So, when we refer to EMR, it is a white light that is a combination of all frequencies. So, based on the frequencies, we have classified the electromagnetic waves. So, before that, we will understand the frequency, wavelength, and amplitude of a wave. So, this is the travel of electromagnetic waves you can see here, right? So, it is traveling. So, now we will understand what we mean by wavelength. So, this is the wavelength; this particular distance is the wavelength, right? And for time  $t_0$ , this was the position at  $t$  equal to 1 second; this is the next position. Between this, we have frequency. So, this is 8 Hz; why is it 8? So, 1, 2, 3, 4, 5, 6, 7, 8 are right, and then comes the amplitude. So, this is the amplitude, right? So, here I hope you are clear about the frequency, wavelength, and amplitude, and also remember that wavelength is inversely proportional to energy, and wavelength is also inversely proportional to frequency. So, these concepts we will be referring to again and again.



So, based on the frequency, electromagnetic radiation has been divided into different groups starting from radio waves, microwaves, infrared, visible light, ultraviolet radiation, X-rays, and gamma rays, and here you can see their distribution. So, this is the 400 to 700 nanometers; this is the visible spectrum, and here we have different colors, and our eyes are capable of seeing this particular wavelength range. So, again, referring to the basic concept. If we increase the wavelength, we are moving towards radio waves from gamma rays. The energy will decrease. So, energy will be high at lower wavelengths, and you can see the frequency is increasing towards shorter wavelengths, right? So, this concept is very, very important because of that, you will be able to understand why longer wavelength region images have coarser or medium resolution or spatial resolution. So, again, I will refer to those concepts. So, let us say you have a sensor that is looking at the ground, right? So, this is one individual detector, and this is the IFOV. Now, the wavelength, let us say, is between 400 and 410. So, the wavelength range is very, very small, right? So, we need a bigger area to reflect more energy that will travel through our atmosphere and into space, and it will reach our sensor. However, if we increase this wavelength to 400 to 2500 nanometers, this energy will be more than sufficient to be captured or identified by our sensor. So, what we will do is try to reduce the size. So, that is why when we have a longer or broader wavelength range, the spatial resolution is less; that means the fine spatial resolution images we can produce. However, when we have a smaller wavelength region, we need to have coarser or medium spatial resolution to produce our images because of the relationship between energy, wavelength, and frequency.

## Electromagnetic Radiation



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The relationship between the wavelength ( $\lambda$ ), and frequency ( $\nu$ ) (*Maxwell*):

$$\nu = c/\lambda$$

where  $c$  (Speed of light) =  $3.00 \times 10^8$  m/s

Note: ' $\nu$ ' is inversely proportional to ' $\lambda$ '.

The relationship between the energy ( $E$ ), and frequency ( $\nu$ ):

$$E = h\nu$$

where  $h = 6.626 \times 10^{-34}$  (Planck's constant).

since,

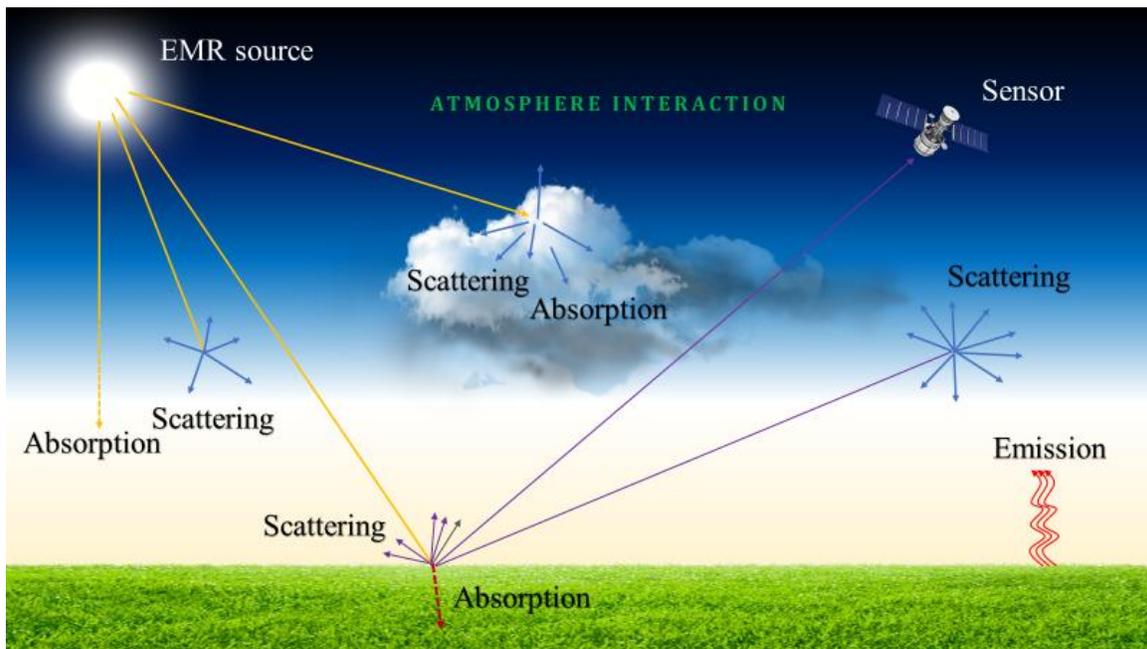
$$\nu = c/\lambda;$$

$$E = hc/\lambda$$

Note: ' $E$ ' is inversely proportional to ' $\lambda$ '.

So, the relationship between the wavelength and frequency is given by  $\nu = c/\lambda$ , where  $C$  is the speed of light, and here we can easily see. That  $\nu$  is inversely proportional to  $\lambda$ . The relationship between energy and frequency is  $E = h\nu$ . So, we can change this, and we

will have  $v = c/\lambda$ , and E is inversely proportional to  $\lambda$ . That means energy is inversely proportional to wavelength, and because of this concept, we are restricted to having better spatial resolution in the longer wavelength region. So, again, going back to the basics of remote sensing: how is remote sensing being done? So, the sun is our source of light, which illuminates the target, and then the light passes through our atmosphere, reaches our Earth's surface, then it gets reflected, and again it interacts with our atmosphere; then it travels through space to reach our sensor, right? So, in this particular process, the electromagnetic light is interacting with our atmosphere twice. So, this twice interaction will have the big role in controlling the quality of the image that we are generating through remote sensing. So, we will understand it here.



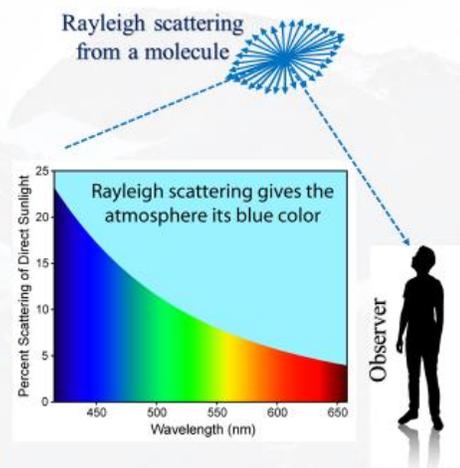
So, this is the incoming radiation. So, which is coming and reaching our atmosphere? In the atmosphere, we have gases, we have aerosols, we have dust particles, we have clouds, and all of them play a big role in interacting with the energy that is coming from the sun. So, once it reaches our atmosphere, some of the energy will interact with the dust particles, aerosols, or the clouds, and then it will get scattered; some of the energy will directly come to the surface, and part of it will be reflected or backscattered. Then again, they will interact with the atmosphere, and the resultant energy will reach our sensor. And we discussed in the last lecture that the energy coming directly from the scattering of the atmospheric constituents is called path radiance, and then path radiance plus the ground radiance together get captured, and we obtain the images. It depends on what the atmospheric conditions are at the time of image acquisition. So, it is not always available in some areas that are free from clouds, free from any atmospheric constituents like gas, and free from dust particles, aerosols, or clouds; that area will have no path radiance.

So, atmospheric interactions. When electromagnetic radiation interacts with the Earth's atmosphere, its speed, intensity, and spectral distribution—that is, with respect to wavelength—get changed because, again, the dust particles also have some sort of chemical composition and internal atomic structure, right? So, they also interact with the energy, and they scatter the energy in different directions, and because of this, the direction may change. So, because of the atmospheric interaction, speed, intensity, spectral distribution, and direction are all changing. So, scattering and absorption are very important processes to describe or understand the interaction of electromagnetic light with Earth's atmosphere. So, the first one is scattering, which causes a change in direction that is unpredictable. Remember that because of the scattering, if the light is changed or the direction of the scattering is changed, we cannot model; we cannot predict. So, efficiency and behaviour depend upon the size of the scatterer and the wavelength of the radiation. So, remember whether the wavelength is shorter or longer. It depends on how they will interact with the atmospheric constituents. So, that is why efficiency and behavior depend upon the size of the scatterer, the aerosol that is present in the atmosphere, and the wavelength at which we are trying to do the remote sensing. So, there are different types of scattering. The first one is Rayleigh, then Mie, and then Non-selective. So, the light is incident, and then based on the size or the diameter of your scatterer, which is present in the atmosphere, the scattering will happen, and the absorption will also take place.

## Scattering: Rayleigh Scattering



- ❖ Occurs when size of the matter is very small than the wavelength...
  - ❖ During scattering, EMR get absorbed and then re-emitted by the atoms/molecules...
  - ❖ Unpredictable direction of emission...
  - ❖ The amount of scattering is inversely proportional to the 4<sup>th</sup> power of radiation's wavelength...
- $$I \propto \frac{1}{\lambda^4}$$
- ❖ For example: blue light (0.4 $\mu$ m) scatters 16 times more than near-infrared light (0.8 $\mu$ m).
  - ❖ Rayleigh scattering is responsible for the blue sky and red sunsets.



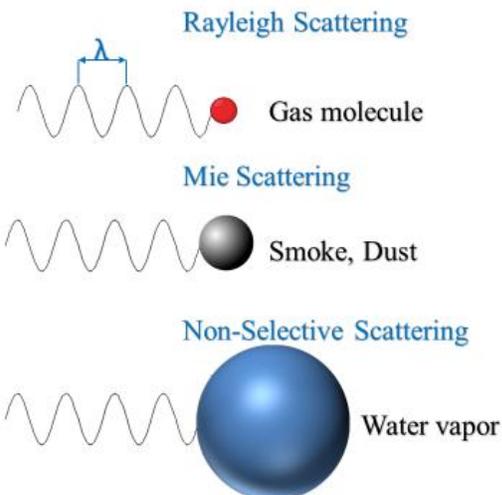
So, we will talk about Rayleigh scattering. It occurs when the size of the matter is much smaller than the wavelength. So, let's say this is the wavelength and this is the size of your scatterer. So, in such a situation, we will have the Rayleigh scattering. During scattering, EMR gets absorbed and then re-emitted by the atoms or molecules. The unpredictable direction of emission; the amount of scattering is inversely proportional to the fourth power

of the radiation's wavelength. So, that is given here. For example, blue light that is 0.4 micrometers scatters 16 times more than near-infrared light, and the near-infrared we are talking about is 0.8 micrometers. So, Rayleigh scattering is responsible for the blue sky and red sunset. So, remember that because of this scattering, we have the blue sky and the red sunset. Now, Mie scattering occurs when there are spherical particles present in the atmosphere with diameters approximately equal to the wavelength of radiation. So, here the wavelength and the scatter are both equal. For visible light, water vapor, dust, and other particles ranging from a few tenths of a micrometer to several micrometers in diameter are the main scattering agents. The amount of Mie scattering is greater than Rayleigh scattering, and the wavelengths that scatter are longer because we are talking about similar sizes of the scatter and the wavelength. So, this slide is meant to explain this scattering mechanism. So, here is the Rayleigh scattering; this is the Mie scattering, where the diameter and the wavelength are both similar. and this is the non-selective. This occurs when there are particles in the atmosphere several times the diameter of the radiation. Water droplets, which make up clouds and fog banks, scatter all wavelengths of visible light equally well, causing the cloud to appear white.

## Scattering: Non-selective Scattering



- Occurs when there are particles in the atmosphere, several times of the diameter of the radiation...
- Water droplets, which make up clouds and fog banks, scatter all wavelengths of visible light equally well, causing the cloud to appear white...
- Scattering have severe effects on remote sensing images where it reduces the information...

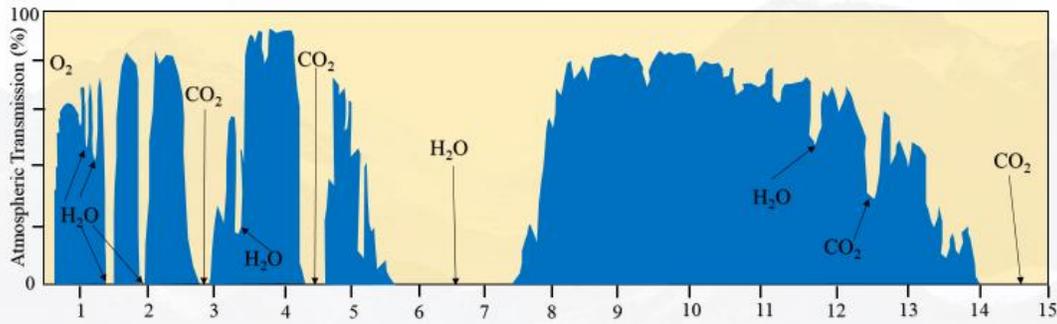


Scattering has a severe effect on remote sensing images when it reduces the information because the light that is being captured by our sensor was supposed to be reflected, emitted, or backscattered values from the surface only. But because of the scattering, we are having the path radiances. Now comes the absorption, a process by which radiant energy is absorbed or converted into other forms of energy.

In the Earth's atmosphere, the following constituents commonly cause absorption. So, here we have water ( $H_2O$ ), then  $CO_2$ ,  $O_2$ ,  $O_3$ , and  $N_2O$ . So, these are playing with our incoming

radiation, and then it is causing the atmosphere to be blocked. These constituents have an important role in the absorption of the energy that is coming from the sun or from the sensor. Right. The cumulative effect of the absorption by the various constituents can cause the atmosphere to close down in certain spectral regions. Now, let us say this is the transmittance of our atmosphere, right? So, this is transmittance; this is wavelength. So, let us say just for example, if this particular wavelength is blocked by our atmosphere, right? Then we cannot use this wavelength for our remote sensing because this wavelength's energy will never get passed through our atmosphere. So, those things are very important and critical to understand which particular wavelength we should use to make our sensor, and then do the remote sensing.

## ATMOSPHERIC WINDOW



- Sensors are designed to operate in these **less affected wavelength regions**.
- **Atmospheric window:** Wavelengths less affected by earth's atmosphere.
- **Other wavelengths are blocked** (completely/partially) by the atmosphere.

So, here you can see that this is the percent atmospheric transmission. So, the green color indicates the amount of transmission. So, you see here it is written that because of the H<sub>2</sub>O, we have this CO<sub>2</sub>, H<sub>2</sub>O, O<sub>3</sub>, CO<sub>2</sub>, and H<sub>2</sub>O. So, because of this, these are not 100 percent right, and some of the wavelengths are completely blocked. They do not have any transmittance from our atmosphere. So, in such situations, it is suggested that we should only go for the wavelength ranges that have some transmittance. So, here, if we select this particular wavelength range to design our sensor, then we will be able to capture the energy. But if we use this particular wavelength range to design our sensor, then we will not have any energy to be captured by our sensor because everything is absorbed by our atmosphere, right? So, the sensors are designed to operate in these less-affected wavelength regions. and these are called atmospheric windows. So, these windows are the wavelength ranges that are less affected or not affected by the atmosphere. Other wavelengths are blocked completely or partially by the atmosphere. So, this is a very important atmospheric

window. So, atmospheric windows are the wavelength ranges that are less affected by our Earth's atmosphere.

So, with this, we will end Part 1, and we will continue this in Part 2.

**Thank you.**