REMOTE SENSING ESSENTIALS
Prof. Arun K. Saraf
Department of Earth Sciences
Indian Institute of Technology Roorkee

Lecture – 44
Radar Images Interpretation and Applications

Hello everyone, and welcome to new discussion on radar images interpretation and applications. And as mentioned in earlier in discussion that, SAR interferrometric we will be discuss after this first we need to understand the power images and therefore, I thought that I will have discussion on this and then we can go for other discussions. So, basically when the images are recorded is especially the radar one which I am discussing that electromagnetic energy in a radar pulse when it meets the surface.

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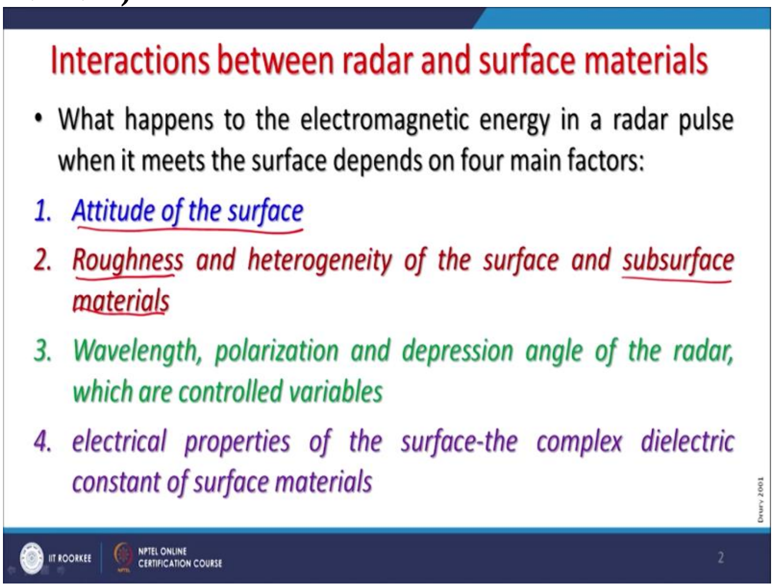

And basically depend on 4 major factors. So, when the satellite or sensors sense the energy or a pulse, radar pulse to the towards the ground and then the surface are the features which are present on the ground and will behave differently based on these 4 main factors. First of all the attitude of the surface how the surface is and how it is oriented, we have seen in case of a hilly terrain.

And slandering distortions that there might be shadow issues that a part of the hill is not getting at all any signal any energy from microwave sensors or there might be 2 other distortions 1 is the foreshortening and another 1 is layover, that the base of the hill is getting first registered and then peak or top of the mountain is getting later. So, that will bring foreshortening. And it just oppose it to this that the top is getting first registered and base is getting later and that being the layover.

So, attitude of the surface which is being illuminated by radar pulses plays very important role in the our power images or SAR images. So, attitude of the surface orientation basically, how it is oriented in which direction it is oriented and how the slopes and other things are there second is the roughness. If surface is very rough and heterogeneity is there are the surface then it will be recorded completely differently and if it is not there, it will be recorded differently.

So, sometimes there might be effects of subsurface features on surface and that may get recorded also. If I take example of a water body, sometimes water body may be very calm, roughness is not there and therefore, it will be recorded completely differently. Then a water body is having a lot of waves same thing is also in which wave length we are using or recording the data because different sensors may be having S band utilization of S band C band or X band the most common one which we have been discussing is C band.

So, what happens that a wavelength and this microwave images are also dependent on wavelength. Polarization we have also discussed whether it is a vertical polarization horizontal or mixed one and also the depression angle of the radar that will also play a important role while images radar images or SAR images are getting recorded. So, these variables will play a very important role in radar images. Now, the fourth main factor is the electrical properties of the surface.

That is a dielectric constant which is a complex thing of surface material a rock, a dry soil or sand and water or vegetation all will have different dielectric constant and therefore, they are electrical properties when influence the recordings in the radar images so, that also plays a very important role. So why we are discussing these factors is because when we get these power images or SAR images.

That in depth, while doing the interpretations, we have to remember these factors, then only a correct interpretation or utilization of application of such images can happen. Now materials dielectric constant controls the proportion of the radar energy reflected by your material and that penetrated into it. Earlier in the discussion also in previous discussion, I mentioned that all courses of Saraswathy River.

We are discovered in dry soil conditions or dry sand condition in Rajasthan because it is possible that these waves microwaves can penetrate into dry soil to large and depth So, this because of different dielectric constant so, materials dielectric constant basically controls the proportion of radar energy reflected via the material and the penetrating into it. So, if it is getting reflected then only it will reach to the sensor.

And if it is getting absorbed, then it will not reach to the sensor and therefore, we will not be able to record that thing. So, in dry sand that energy, the initial part and the from top soil sand it gets reflected and get recorded. But as soon as it encounters moisture or water, then the behavior is completely different and it is observed and you do not get the recordings.

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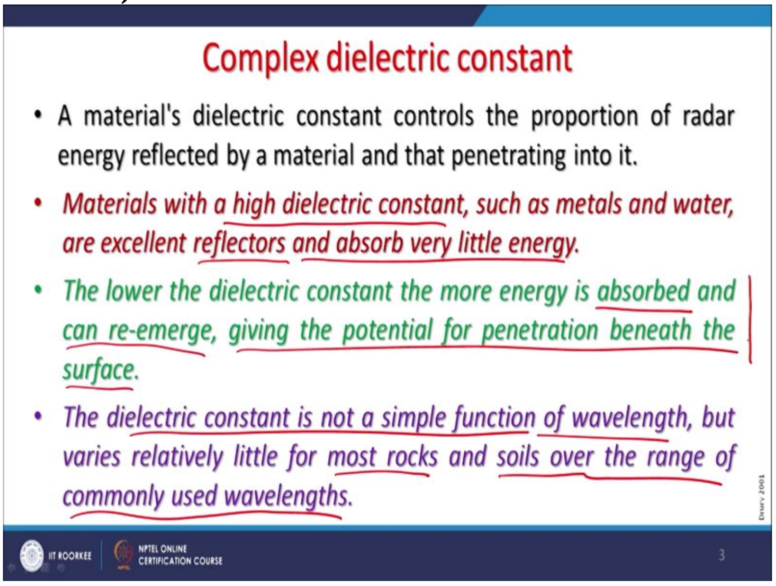

So, materials will the high dielectric constant, such as metals and waters and water are excellent reflectors and absorb very little energy and therefore, that is why I said that surface roughness of water also plays very important. So, they are also it will play a very important role. So, the energy which is not absorbed gets reflected. So, lower the dielectric constant more energy is absorbed.

And that can and re-emerge giving potential for penetration beneath the surface. So, what happens that in case of dry sand that it is having low dielectric constant and the energy lower the dielectric constant the more energy is absorbed and giving the potential. So, this will give potential for penetrating the waves and then therefore in the dry soil it can penetrate. So, dielectric constant is not a simple function of wavelength.

Because in different bends, it will behave differently but not only depends on wavelength, but also it varies relatively for rocks and soils over the range of commonly used wavelengths. So, different rocks size and water content motion content that will allow to behave differently because all these will have different dielectric constant. So, materials with high dielectric constant such as metals and water are excellent reflectors.

This is exploited too and for radar images for geo referencing purposes. So metal reflectors are kept when data is being acquired by the satellites or we call also called corner reflectors and therefore, the reflection is maximum from these reflectors which are you know like a triangle kind of thing open triangle. So, whatever the signal microwave signal which is coming from the sensor hits these metal reflectors corner reflectors.

And because they are having a high dielectric constant, they reflects back the maximum energy so in your power images, these corner reflectors will have a very bright signature and therefore, it becomes very easy to identify them and then once the location of these corner reflectors is known through the DGN GNSS or DGNSS, then these locations can be used to geo reference images.

So, the property of different metals or water can be explained sometimes when it is not possible to have corner reflectors, but if we are having calm water then that can also be used if a small water body and that it reflects the maximum microwave energy, then that can also be used as a GCP ground control points for geo referencing because it is going to absorb very less energy and the low lower dielectric constant.

The more energy absorbed and can re-emerge, giving the potential for penetration beneath the surface. So, this says this characteristic prevails in the dry sand. Their water is would there high dielectric constant is not there measure is not there, and the energy is absorbed and can re-emerge. So, continuously you are getting and it is allowing the energy or the microwaves to penetrate and through these dry sand.

And the you know the old courses of Saraswathy River where when the boring or drilling was done and you know the water was found there and it penetrated very many meters 15 to 20 meters in dry sand. So, that is the complex dielectric constant can be exploited, differently high dielectric constant can be applied can we applied for creating or using GCPs corner reflectors as GCPs.

And this, low dielectric constant material are sometimes useful to find out measure water beneath them. Now, these are dry soils and rocks, which we just mention.

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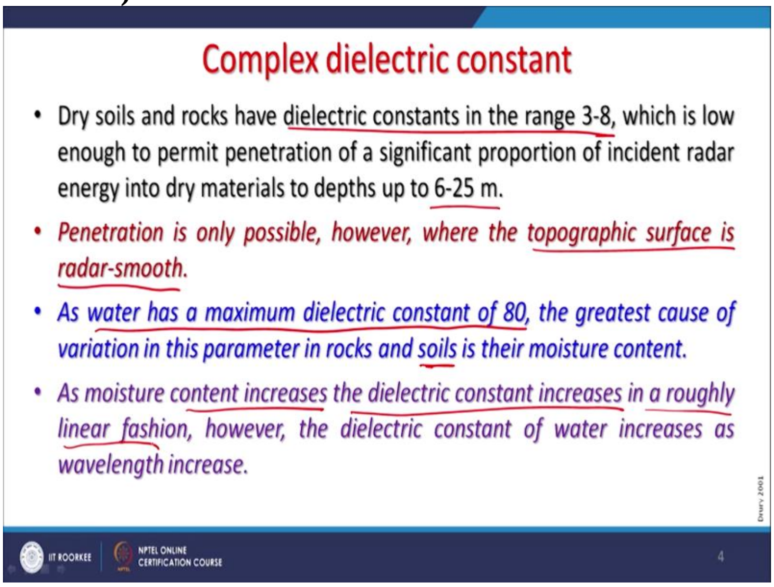

And dielectric constant in the range of 2 to 8, which is enough to permit penetration of a significant portion of incident radar into dry materials to depth of even up to 25 meter. In desert conditions, you do not have moisture in the sand. And therefore, because of a very little dielectric constant ranging from 3 to 8, which will allow the penetration and therefore, as soon as it encounters the water body.

Then it is a different situation and the dielectric constant will be high and then you get a reflection from there. So, you can that is the big one of the biggest advantage of using remotes and active microwave data is that in dry sand condition dry soil condition it can penetrate into the ground. So, penetration of microwave signals is only possible where the topographic surface is radar smooth.

Radar smooth means set like in desert conditions. If there are a lot of undulations, though the soil may be dry or sand may be completely dry is still it may not work. So, you need a completely flat terrain as it is mention is radar is smooth, then only you can have the success. So, in desert conditions where you do not have many dews, sand dews terrain sometimes is very flat.

Not many (()) (14:22) features their radar remote sensing can work to find out water bodies which might be even at greater depth even up to 25 meter. This as in the example I have given of Saraswathy courses and in other countries also this has been used. Now, here also mention the water is a substance which has got the highest or maximum dielectric constant about 80.

And that is the greatest cause of variations in the parameters of rocks and soils in there moisture content that plays very important because soil at different depths we have different content of water or moisture conditions and therefore, the soils will have more influence and because of dielectric constant because of availability of moisture and therefore, they will get different recordings in the images or radar images or power images.

So most as moisture content increases, the dielectric constant also increases and in a roughly linear fashion however, the dielectric constant of water increases as wavelength increases. So, different wavelengths if we use then you will have different are as longer the wavelength you go the dielectric constant value will also increase. Generally as I have said that the radar remote sensing is being done either using C band S band or X band.

So, depending on which band data C band is the most common we will also see later and of a different this we have already discussed the different senses but, when an improper time comes we will again see that one. So, this say dielectric constant.

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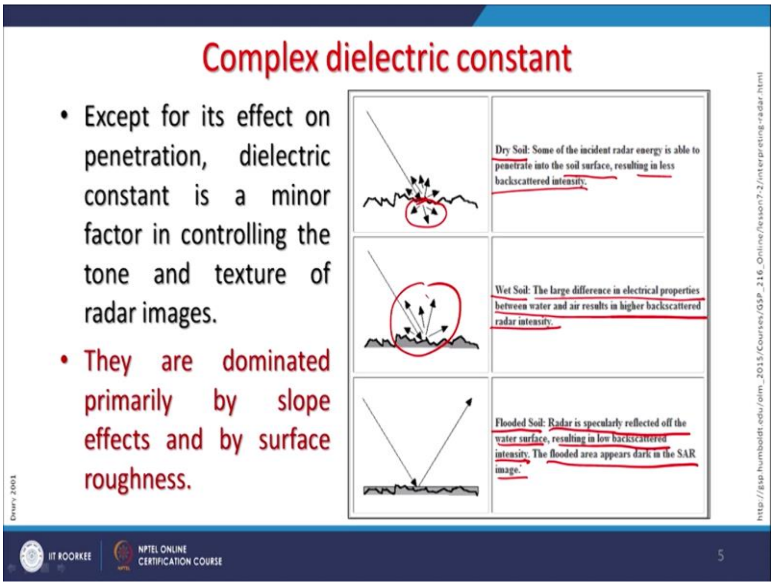

For example, in the soil, some of the incident radar energy is able to penetrate into soil surface resulting in less backscattered intensity. So, absorption is there, as you can see that some part is penetrating whereas, wet soil that means high moisture content and that means, large reflection because water content is more. So, the large differences in electrical properties between water and air results in higher backscattered radar intensity.

And you get because the images which we see SAR images are nothing but the intensity images, the backscattered intensity image and therefore, these things we must understand to identity different objects in this SAR images. So, if you are getting darker signatures. That is intensity is low that might be due to absorptions or microwave energy. If you are getting very bright signatures that might be due to the reflection because of high dielectric constant because of high moisture content likes this scenario.

There might be situation where entire energy is reflected in just 1 direction that is like flooded soil so radar is a specularly reflected of the water surface resulting in low back scattered intensity. The flooded area appears dark in SAR images. So, if a specular reflection happens, then even the water body will also get registered as black because less backscattering that means in intensity made it will have less value.

And therefore, if we assign and grace it accordingly then be these areas might appear as black because of its specular reflection. So, dielectric constant except for its effect on penetration. Dielectric constant is a minor factor in controlling the tone and texture of radar images. These are dominated primarily by slope effects and why surface roughness. So, surface roughness is one of the factors which we have already discussed plays very important one.

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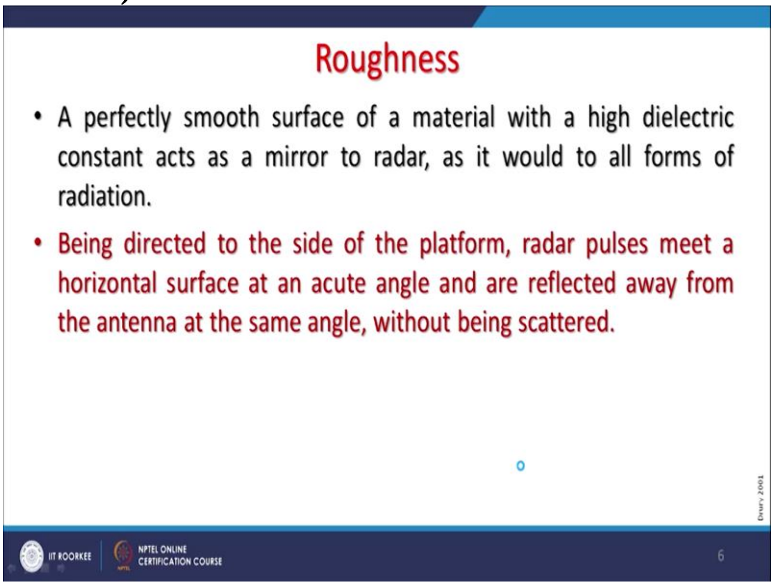

Roughness the surface roughness in a perfectly smooth surface of a material with high dielectric constant act as a mirror to the radar and it would be to all forms of radiation. So, they behave water body may behave as a complete mirror, because water is having dielectric constant, a smooth surface a calm water may behave like a mirror so, being directed to side of the platform.

Radar pulses meet a horizontal surface at angle acute angle and are reflected away from the antenna at the same angle without being scattered. And therefore, there you see a mirror effect this specular reflection basically results in a totally black signatures for a smooth surface. So, if the entire energy is getting reflected, and in a direction where we do not have the receiver or a situation.

Then these will appear as black. Now, the surface smoothness or roughness in respect to radar depends on the wavelength because if a wavelength is long, the this a smoothness surface will behave differently whereas, if it is sought, it will behave differently so, incident angle not only that depends on wavelength.

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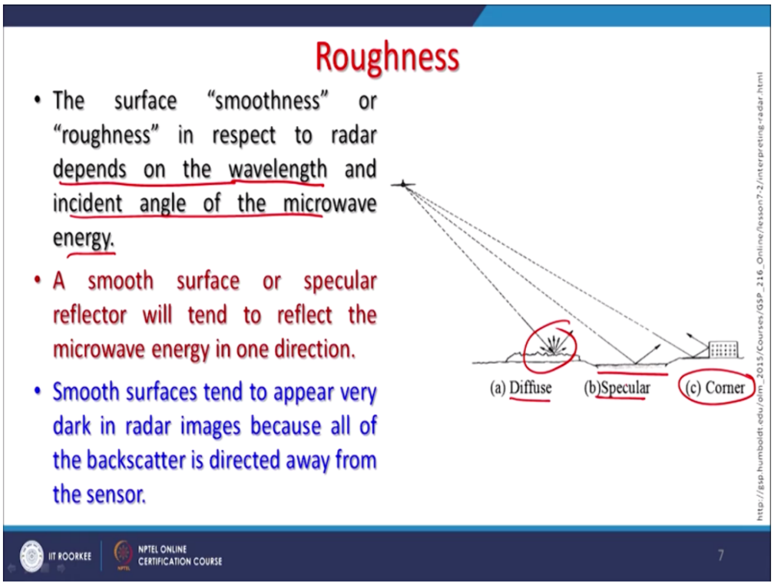

But also the incident angle of the microwave energy. As soon here that we may have a reflection like a diffuse reflection, specular reflection or a corner reflection and corner reflection that means, the maximum energy is going back to the radar. So, these corner reflectors the metal corner reflectors are used that is why they are designed in a manner that the maximum microwave energy is reflected back immediately to the antenna or receiver.

And therefore, they will appear very bright signatures in your radar images. But there can be other diffuse reflector in case of dry sand or maybe dry vegetation, there may be a very smooth surface like this, then you may have a specular reflection. So, a smooth surface or specular reflector will turn to reflect the micro energy only in one direction not in order and therefore, it do not goes back to the sensor or receiver.

And this surface will be recorded as a dark signature though the reflection is very good but a specular reflection so, the smooth surfaces turn to appear very dark in the radar images, because all the backscattered is directed away from the sensor. So, all the time this intensity image cannot be adjust interpreted like this there might be reflection of different kinds diffuse, specular or maybe because of corner effect. So rough and that is lambertian or diffuse the surface.

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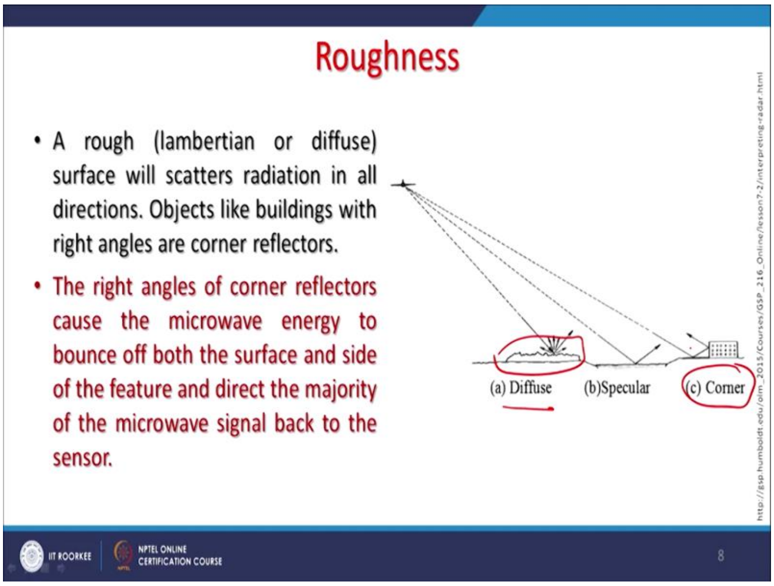

As we see here because of a surface roughness on the surface will scatter radiation in all directions as you can also see here and objects like buildings, the right angle are corner reflectors, so, if they are coming in that kind of right angle situation with reference to your receiver and then they are they become a corner reflector very good reflector in right angles to the corner reflectors cause the microwave energy to bounce off both the surface and side of the feature and direct the majority of the microwave signal back to the sensor.

If somebody is not having metal and corner reflectors, but if because of these buildings if a such situation is there, these 2 can be used as a GCPs for geo referencing radar images, because otherwise geo referencing of radar images becomes difficult people merely rely for geo referencing on orbital parameters. Rather than using GCPs if we use the GCPs like these corner reflectors, maybe metal or maybe because of some building and artificial manmade structures, then our geo referencing can improve significantly. Now, roughness different examples are given here.

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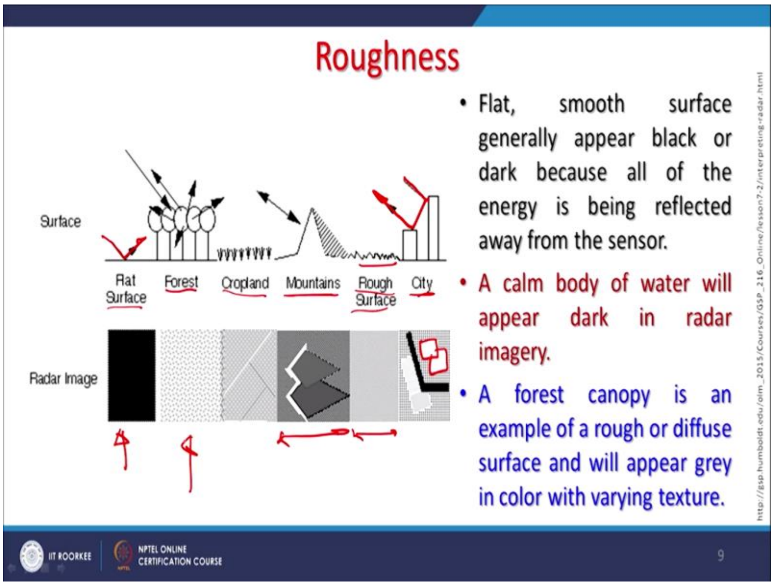

What we see that a flat surfaces there, then you are having a forest, you are having a cropland different surfaces, different roughness mountains will have their own appearance rough surface here which you see here or city which is providing might provide corner reflection. So, in radar images how these will be recorded, if it is a flat surface and a specular reflection is happening.

That means a the back no backscattering is reaching towards the receiver, then you will get a complete dark signatures in the image. But if you get a this because of roughness diffuse reflection, maybe because of forest in that means backscattering in all direction and therefore, you will have a something like grey and dotted kind of signatures in your radar image.

Whereas in cropland might be more smoother than forest and it will have recordings approved accordingly where in case of mountains you have seen because of shadow because of layover or because of foreshortening, you may get recording something like this depending on the orientation of the hill with reference to the sensor, if a if the surface is rough then you may not get complete flat surface but a rough surface small undulations are there.

Then it will not get a specular reflection but it may be a mixed kind of diffuse and specular and therefore, you will get the recordings in the midrange not black normal, full reflection corner reflection but in the middle, maybe gray kind of situation. If you get a corner reflector as you can see here that the wave is coming going back and then going back immediately. And through this backscattering and therefore.

They will appear very bright signatures as you can see here. So, the surface roughness plays very important role in case of radar images. So, flat smooth surface generally appear black as you have seen in the first example or dark because of all the energy is being reflected away from the sensor. A calm water body will appear dark in radar images. Because it is having specular reflection the forest canopy the second example here is an example of rough or diffuse surface.

Diffuse reflection and will appear grey in color or grey shades in with varying texture in your radar images whereas refresh a rough refers a rough surface is scattered more energy in all directions including back to the sensor and appear brighter like forest example, might be there or rough surface this example.

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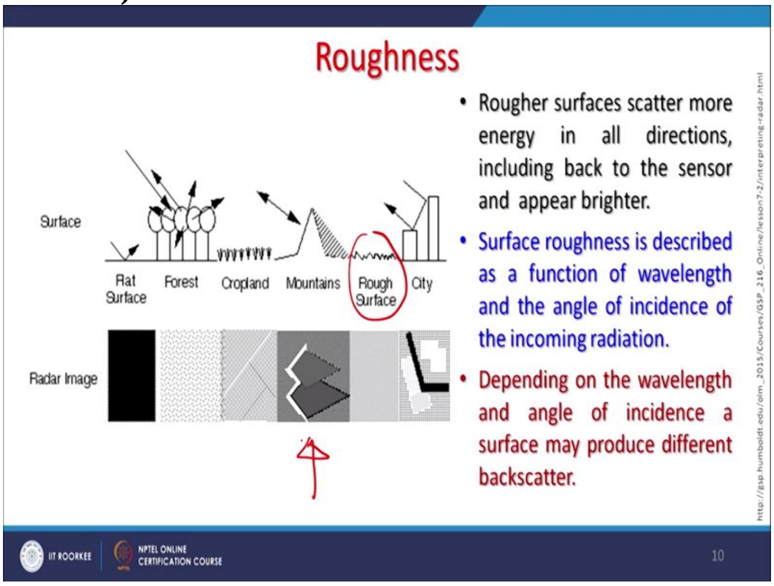

And surface roughness is described as a function of wavelength depends on wavelength definitely, and the angle of incident of incoming radiation how it is located with reference with incident angle that matters lot especially in hilly terrain like this example, here are mountains are there and depending also the roughness also depending on the wavelength and angle of incident to surface may produce different backscatter. Now, if I take example of plants, trees in different bands how it behaves because now we are changing the wavelength, but the objects are keeping same.

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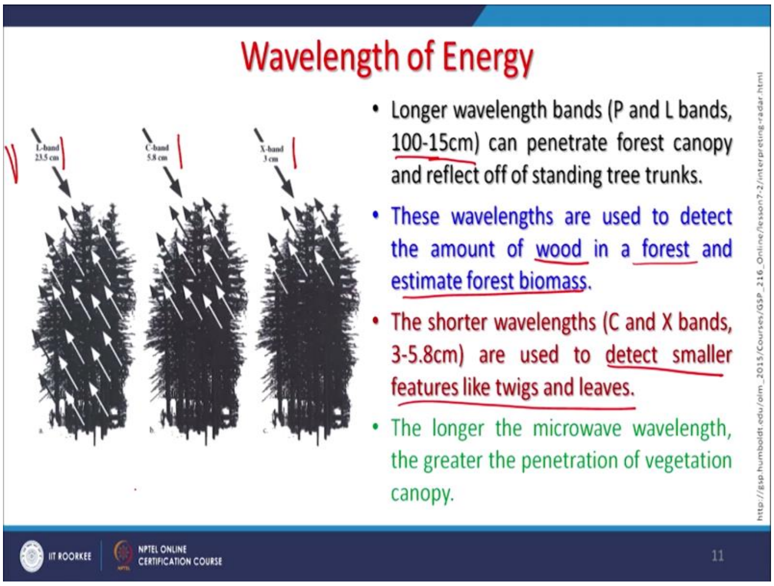

So, this is L band whereas, wavelength is 23.5 centimeter C band the second one middle example is C band 5.8 most common used in radar remote sensing maybe X band that is 3 centimeter. So, here in the L is having maximum wavelength X is having minimum wavelength in this example. So, what we see here that the white arrows are swing the back backscattering.

So, more back a backscattering is occurring in case of long wavelength and less backscattering is occurring in case of X band or short wavelength and of course, the C band is in the middle. That is why this band is most commonly used currently so, longer wavelength bands, maybe be P L bands which are having 100 to 15 centimeter can penetrate forest canopy and reflect of the standing tree trunks.

And this is the example of L band in the first scenario, because we are having the wavelength between 100 to 15 meter. Therefore, the longer wavelength can penetrate into tree. They can even record the information or reflection by the tree trunk. So, if an application requires you know investigation in a forested land then users should look for L band radar images rather than C band or X band.

Because of penetration capabilities which is depending on the wavelength, longer the wavelength, higher the penetration. Now, these wavelengths are used to detect amount of wood in a forest and estimate forest biomass. Shorter wavelength relatively compared to L band the C band which is a middle range is 5.8 centimeter and also X band which is quite close 3 centimeter are used to detect the smaller features like twigs and leaves.

So, for forest purposes all 3 can be used, but if I want to record you know get the information about the availability of wood that trunk part and they have estimated the forest biomass, then the best is L band. But if I want to record or get the information about leaves or small branches, twigs, then I may use band C or X in case of vegetation. Longer the microwave wavelength the greater the penetration of vegetation canopy be that I have already told you this is what it is reflected.

You see that the L band that a long wave and microwave is reaching and getting backscattered whereas, C band is not penetrating to that extend as L band the relatively X band is highly penetrating only from the top part it is getting backscattered.

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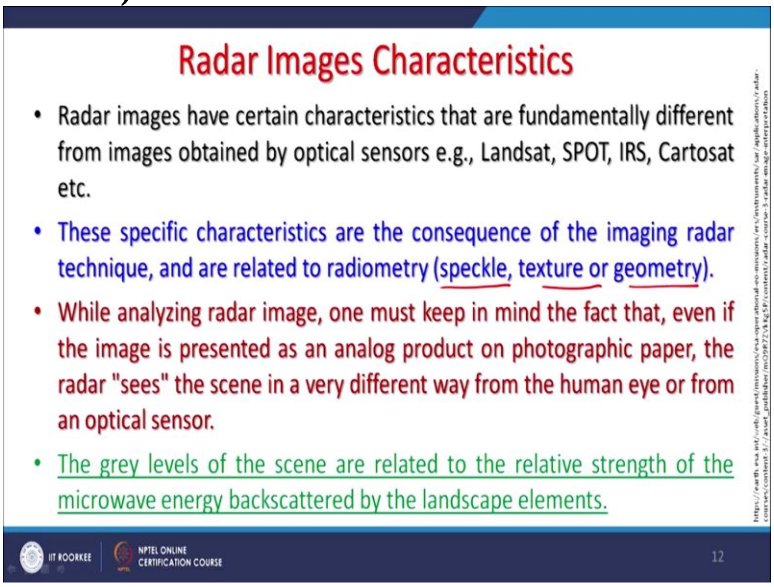

Now, these are a radar images have certain characteristics that are fundamentally different from images obtained by optical sensors. This I have been telling the radar images, interpretations and analysis of radar images is completely different than images which are coming from optical sensors, for example Landsat, SPOT, IRS, Cartosat etc. These characteristics or special characteristics are consequence of imaging radar technology.

And which are related to radiometry that is speckle texture or geometry. So, these are different product altogether radar images. So, when using these images or analyzing these images, one must keep in mind the fact that even the image is presented as an analog product on your photographic paper or on a screen the radar sees the scene in a very different way from the human eye or an optical sensor.

Because as we have discussed that because of dielectric constant because of the surface roughness, it records differently the same material or same objects are recorded differently if they are having different surface roughness, I gave the example of water that calm water of a lake or sea will get different recorded recording then it will calm water will reflect maximum in backscatter.

Maybe specular may get recorded and completely differently as direct objects. And the grey levels basically, the levels are supposed to record the energy strength intensity, but because of certain reasons sometimes even a specular reflection can get very low recording or low grey level so, gray levels of the scenes are related to the relative strength of the microwave energy backscattered by the landscape elements or objects of the ground.

But again not all the time. So that one has to remember what kind of reflection it is there for different objects. Now let us see some examples of and these radar images.

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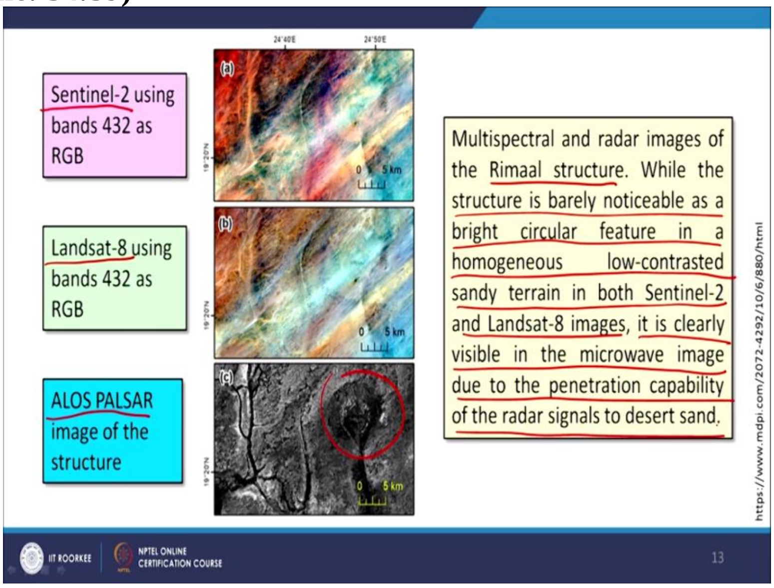

And the first 1 for the same area having different see here, the first 1 is from Sentinel 2 and this is of course not radar image. This is a band combination 432. These are multispectral images. The next one is also multispectral image, but the bottom 1 is the ALOS PALSAR image, which is a radar image and as you can see that these 2 top 2 examples from Sentinel 2 and landsat are giving though colors.

But only surficial information for the same area when we see the radar image from a ALOS PALSAR ALOS is the name of the satellite PALSAR is the sensor, microwave sensor, we see lot of details even about the drainage system or some geological structures, because of different rocks might be present which is completely missing or hardly seen in top 2 images a and b.

So, this structure is Rimaal structure which you are seeing here, which is not clearly seen in these 2 optical images. So, while the structure is barely noticeable as a bright circular feature in a homogeneous low-contrasted sandy terrain in both Sentinel and landsat image. Because this area is covered with sand and top surface in optical images, is hindering that structure Rimaal structure to be seen.

But when this dry soil is their top of the surface, but in radar can penetrate, and therefore, it is possible to see that Rimaal structure very clearly in radar image. So it is clearly visible in the microwave image due to the penetration capabilities of radar signals in deserts sand. That is the advantage of using radar images. So, what people do nowadays, they imply both they imply optical images and also radar images.

These power images are SAR images and can create a in a combined product to diffuse product merge product to get the colors from the surface multispectral information and as well as depth information of a dry area from the radar images and the products can be much more useful than end user. Here also few examples.

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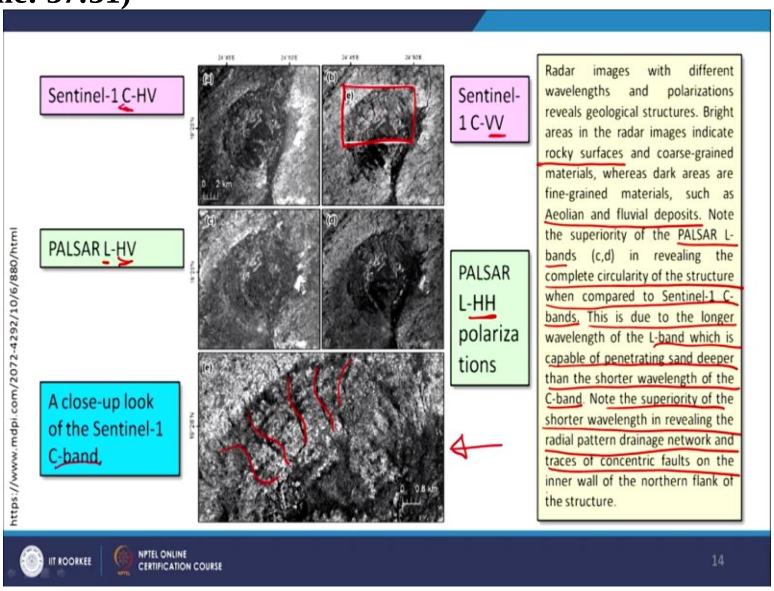

And examples with the 4 different polarizations here that might be a question what happens with different polarization. So, and the Sentinel-1 example of this is C band horizontal vertical polarization. This the first example, for the same area Sentinel VV polarization vertical polarization the PALSAR L band allows PALSAR we have seen the example in the previous image this is L band.

Whereas Sentinel-1 is having C 1 PALSAR L band HV and then PALSAR L having HH polarizations. And when this is a close up from the C band that is the Sentinel of this part which you are seeing here in the e figure. As you can see that the polarization will bring different scenarios or different images. So, when the data is acquired data is acquired with different polarizations.

So, if one polarization is not giving those kind of details one can explore the other polarization images as shown here, 2 sensors and both sensors are having different options available. So, if I take the first 2 images a and b, one is HV, second 1 is VV in case of PALSAR L band HV and HH. So, radar images with different wavelengths and polarizations reveals geological structures maybe a little differently.

Bright areas in radar images indicate rocky surface means high backscattering coarse grained materials, whereas the dark areas are fine grained materials more absorption and which is common in desert conditions in the Aeolian and fluvial deposits. This the superiority of L band that is in c and d relatively revealing complete circle is circulatory of that structure which compared to the top one a and b.

Here this circular structure is much more clear as compared to C band is I have been mentioning that purpose would be known if for vegetation is a different scenario for dry areas different wavelengths different polarization. So, if we see that compared to Sentinel, this PALSAR images that is L band is showing much more better signatures however, HV is showing little differently and HH polarization is showing differently the same structure.

So this is due to this, because this is C C band is not showing as clear as L band, because due to the longer wavelength which L is having this we have seen that what L band is L band is having your 23.5 and C band is having 5.8 this one has to remember. So, here, because of longer wavelength the penetration is much more and which is capable of penetrating sand deeper than the shorter wavelength.

See this structures are visible on surface, then even optical images can reveal them very nicely. But sometimes when these geological structures or maybe some other structures if they are hidden because of sand in desert conditions, then radar images can be very useful because these can penetrate through and rise and so, longer wavelength for example, here the PALSAR is capable of penetrating more.

As compared to shorter wavelength 5.8 that is C band. So, superiority of the shorter wavelength in revealing that radial pattern drainage network and other things are better here as compared to PALSAR. So, both are useful one if all are available, this is e part which is being discussed here. Swing the drainage network very clearly here so for identifying the drainage network, which is very close to the surface might been.

Then a C band data radar data is more useful as compared to PALSAR. But when we want to reveal the underneath the sand dry sand structures, then L band might be useful if all data is available then a combined product if you a diffuse product can also be created.

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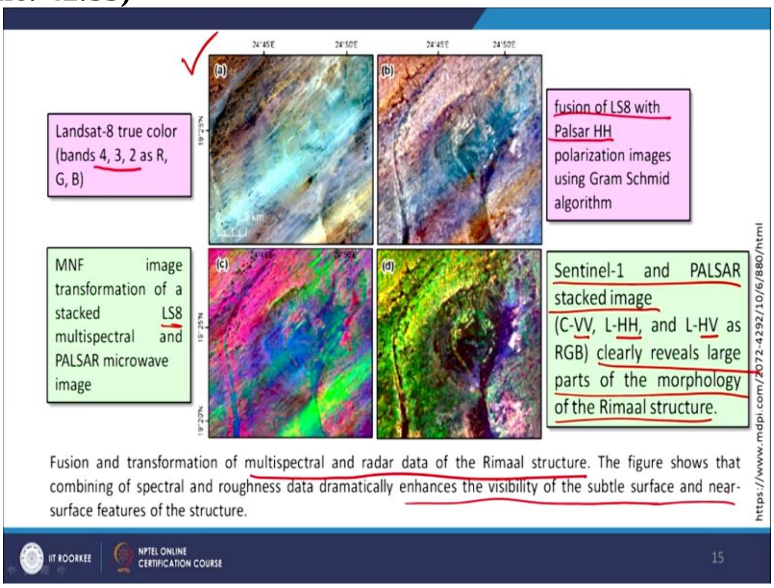

Now, as I was saying fusion of images, so, this is that example is here that that a is a true color image color composition band 4 3 2 have been arranged in RGB that is a part again of a desert area. And b is the fused image of landsat 8 that shown at 8 and has 8 PALSAR horizontal polarization. So, when you merged these 2 this kind of product can be generated, which is much more informative much more useful than using individual product like landsat separately or PALSAR HH separately.

Similarly, in this MNF image transformation a in this landsat 8 and multispectral PALSAR image which you are seeing in c, and sentinel and PALSAR can also be stacked together with 3 polarizations VV HH and LHV. And this combination 2 radar images, 3 different polarizations can reveal much more than any other 3 examples. So, this is clearly revealing large parts of morphology of the Rimaal structure.

Now, this is the depends on the location area to area. Therefore, if options are lot of data from different sensors radar and optical sensors are available, one should try to create these fuse product merge product and see and assess that which one is giving a better results, this cannot be standard for all the areas for all the images or combinations no. Only in this example, this has worked very well.

So, fusion and transformation there is color transformation or RGB transformation of multispectral and radar data can reveal a lot of structures in this example Rimaal structures and combining this spectral and roughness can change or enhance the visibility of the subtle surface features or near surface structures also. And this is what you see here.

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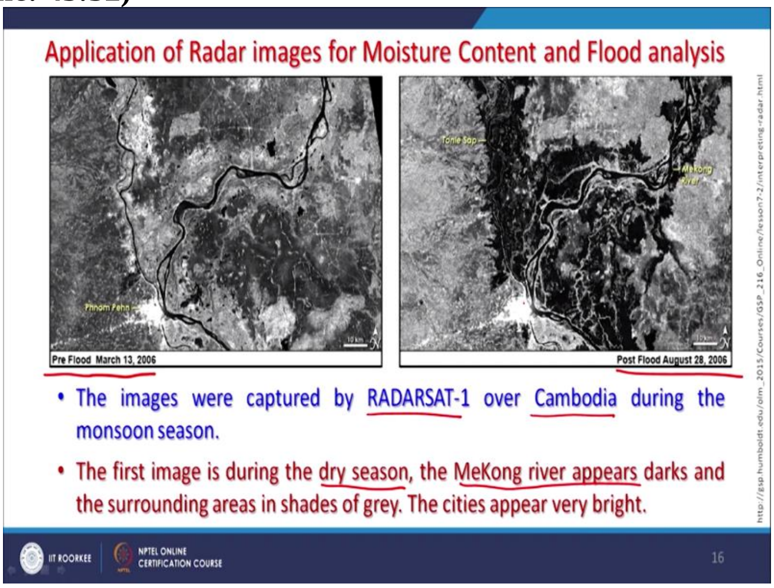

One more example and that radar applications of radar images for moisture content in flood analysis, as I have said that in case of flood the water is calm and therefore, there can be a specular reflection and then therefore the area may appear completely dark the flooded area this is what you are seeing the left side and that is the pre flood scenario and this is the post flood and large area is inundated and appearing as dark.

See the role of or application of radar remote sensing is much more in case of cloudy conditions that we have discussed because you know that the microwave or that wavelength, whether is L X or C or whatever, are larger than your constituents of atmosphere and therefore, these can penetrate through the clouds very easily or aerosols and they play very important role in such studies when you are having cloud.

So, optical remote sensing will not work may not work during floods. Whereas, radar remote sensing it is not affected because of cloud or aerosols or any other thing can work very well and reliably, the inundated areas can be mapped very accurately very successfully. So, that is the best part of radar remote sensing, which allows the penetration another advantages in daytime or nighttime anytime, can these images can be acquired.

Whereas for optical remote sensing you need reflection and you know the illumination source that is the sum. So, images of this our RADARSAT 1 of Canada of Cambodia during the monsoon season or monsoon flooding which you see here. Of course, the first image is the pre flood that is the dry season or MeKong river, which only the river is appearing dark it is having water. But here and a lot of the area which got inundated is appearing dark.

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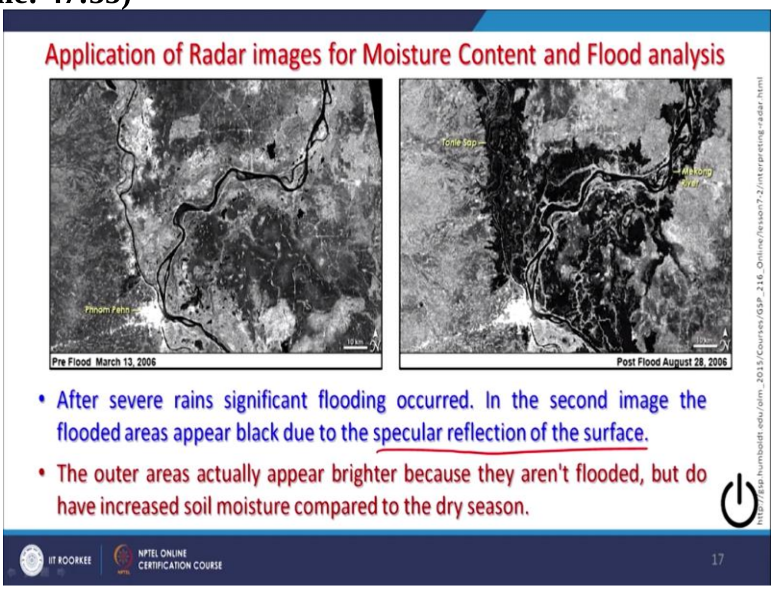

After a severe rains significant flooding occurred in this semi calm river and of course, the second image appears flooded and black due to a specular reflection of the surface. So, as we have been discussing, that water is having very high dielectric constant though it can reflect the maximum microwave energy, but because of calmness, smooth surface, specular reflection can occur and water may appear completely dark.

Calm water will appear dark and this is what you are seeing here. So, one has to interpret images accordingly and then of course, and their applications and their applications can be done very successfully. So, this brings to the end of a brief discussion on basically how to use how to interpret or analyze the radar images or we say density images or also sometimes is called power images.

So, this way we can understand these images which are completely different than what you see in optical images. So, this brings to end of this discussion thank you very much.