Geographic Information Systems
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Lecture-37
Various Techniques to Generate Digital Elevation-2/3

Hello everyone! and welcome to the next discussion which is related with techniques to generate digital elevation models. This is the second part, one more part we will have later. In the part-1, we have discussed nearly various types of techniques to generate digital elevation models and we also focus mainly on how we can employ a survey toposheets to generate digital elevation models, implying the spatial interpolation technique or GIS.

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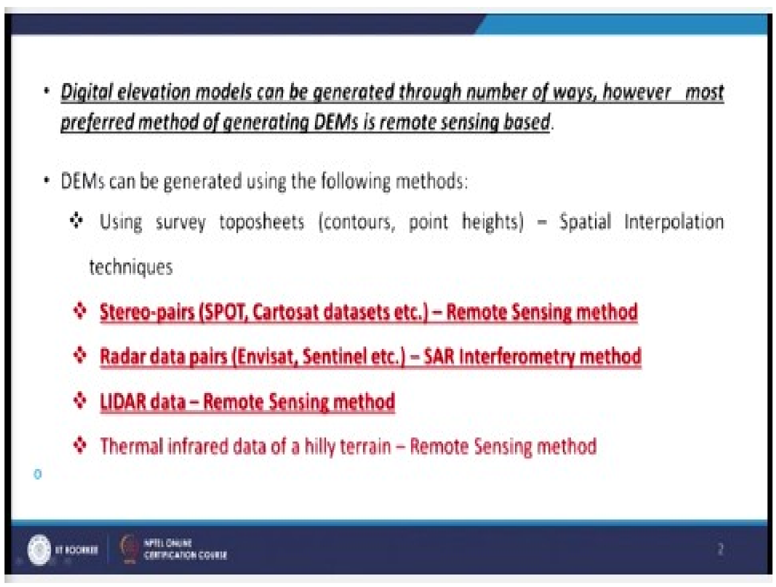
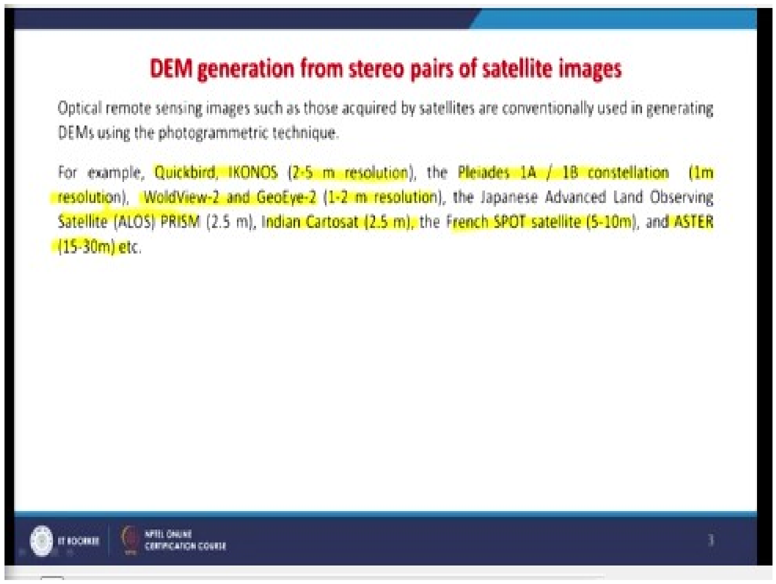


But here we are going to focus more on how this radar remote sensing can be implied? and then we will see that what are the limitations? and what are the advantages? So, as you know that your digital elevation models can be generated various ways, we have already discussed these methods. And this is what we are going to discuss, the either stereo pairs, Cartosat's, radarsat's or other things. **(Refer Slide Time: 01:41)**



So, in this particular discussion, we will focus mainly on the implying this radar data before that about implying stereo pair also. As you know that for this you need an optical remote sensing images which are acquired by the satellites and then implying photogrammetric techniques, we can develop digital elevation models. For example, there are various satellites, though the journey started using stereo pairs and generating digital elevation model with SPOT.

But SPOT is no more in space. So, there are various other satellites which are providing data. For example, IKONOS satellite or Quick bird satellite they can generate digital elevation model at 2 -5 meters' resolution. Now Pleiades 1A and 1B constellation, they can allow us to generate 1-meter resolution but currently it is very expensive data. Worldview-2 and GeoEye-2 also, they can allow us to generate digital elevation model at 1 to either 2 meters. So, for these satellites, which I have discussed you have to buy the data and which is very-very expensive.

So, unless it is really required to have a digital elevation model at 1-2-meter resolution, then one should think of implying that stereo pairs of these satellites for generating digital elevation models. Whereas one should try to resort to the free data like ALOS data or Indian Cartosat data or French satellite 5-10 meter or ASTER data which is 15-30 meter. In many cases, we have found through our practical experiences that even-30-meter spatial resolution digital elevation models are quite good. And if you go for 30-meter spatial resolution digital elevation models, then there are various options which are available to us.

Starting from SRTM DEM that is also available as 30-meter, ASTER which is also available at 30-meter and then our Cartosat for entire India is freely also available at 30-meter. Though, if you buy the data and process it using photogrammetric techniques, you can definitely can create a digital elevation model at 2.5 but that will cost. So, if it is possible then you can go a little bit for 15-meter, if it is available free because if someone is working in a project which covers a large area of the earth then it would be really very expensive to buy, unless it is required, if it is not required why to imply that one?

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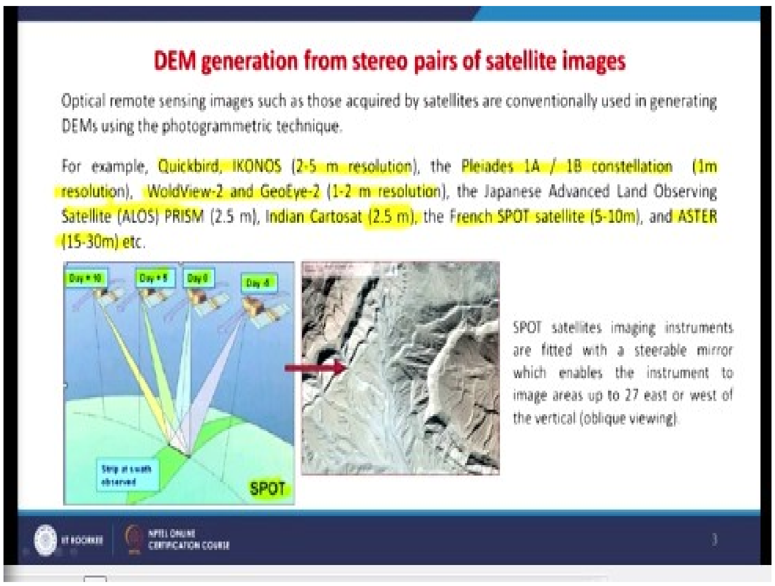

Now, like in case of a SPOT how these stereo pairs were used? Here the example is given that on day 0, it was acquiring the same part of the land as 5 days before or 5 days later or 10 days later. So, if you are having multiple coverages of the same area with different angles then generating stereo pairs is not difficult. And once you are having good stereo pairs without any cloud cover differences between 2 pairs or 2 photographs then it becomes much easier to generate a digital elevation model.

And this is what on the right side you are seeing that this is how the digital elevation models can be generated Implying this technique.

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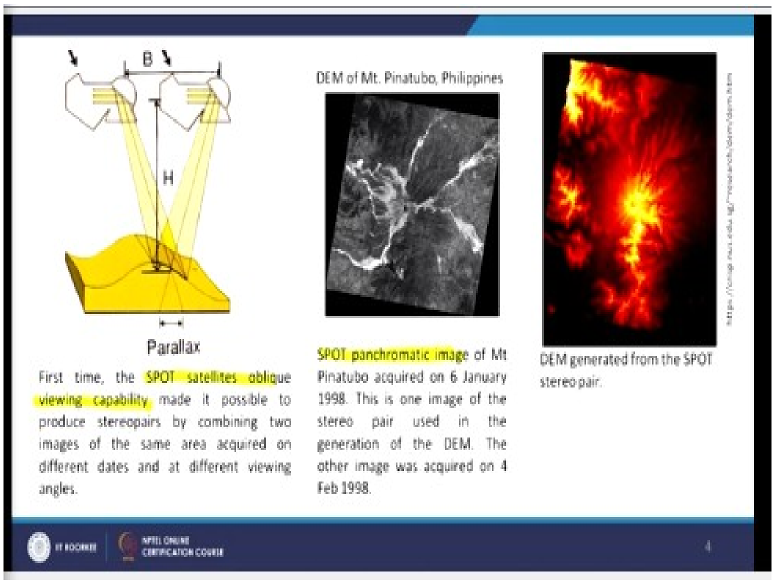

But, I also mentioned in the previous lecture that our Cartosat does not look sideways, it looks Fore and Aft means in forward and after mode. And in which you do not have to wait for another overpass to complete the stereo pair. Stereo pair is generated within few minutes during a single overpass. So, that was the biggest innovation was done in case of a stereo pair generation towards a development of digital elevation model.

Further, on this SPOT satellites the oblique viewing capability that is very much required. Because the same terrain has to be recorded with 2 different angles then only a 3D perception would develop and then, that one can be used to generate digital elevation models. So, like implying a SPOT stereo pairs panchromatic images, this is another point. These stereo pairs are used when we go for digital elevation models, they are always used in panchromatic, that is in black and white.

So, this is a mount Pinatubo of Philippines for which a pair was acquired and then you see a digital elevation model was generated using the same, so not a big difficulty here.

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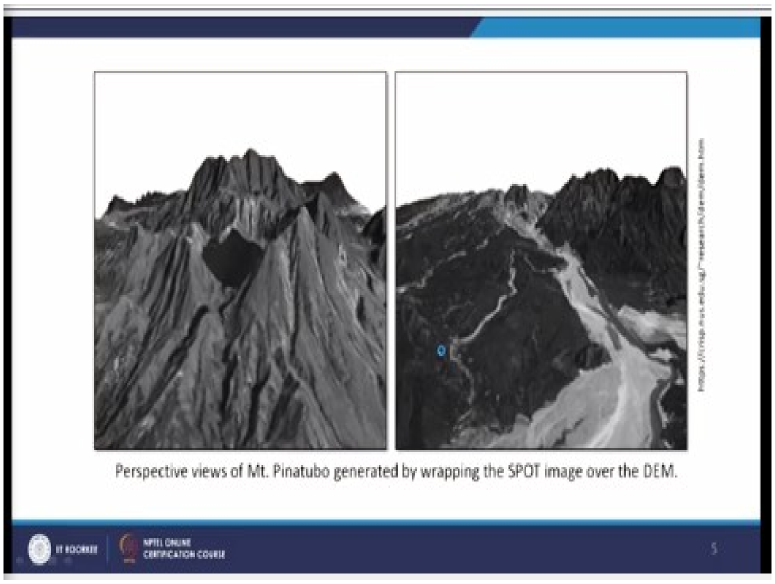

Similarly, once you are having a digital elevation model and if it is possible, if you can drop a satellite image over it then you can create a really the 3D perspective view which will give you a good feeling about that area. So, it becomes much easier once you are having a digital elevation model. Now, I would like to discuss Cartosat, which I have been mentioning.

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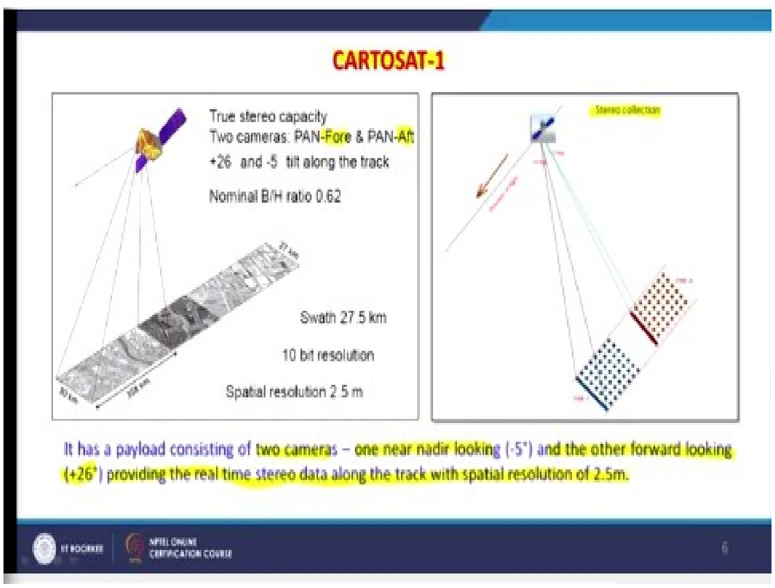

It looks forward and backward during the same orbit data acquisition. So, when it keeps doing like this then at the same time you are getting data. And differential cloud cover or other metrological conditions will not have any significant role. Whereas in case of SPOT, it was a real challenge to get in both photographs or one single stereo pair completely identical metrological conditions but in case of Cartosat it is possible.

So, they have implied 2 cameras, one near nadir looking that is -5 degree and other forward looking that is +26 degree and providing the real time stereo data along track the spatial resolution of 2.5. The optical images may be of 2.5 but when you generate a digital elevation model, you may not end up with the same spatial resolution, you may end up with little lower, that means maybe 4-meter, maybe 5-meter spatial elevation.

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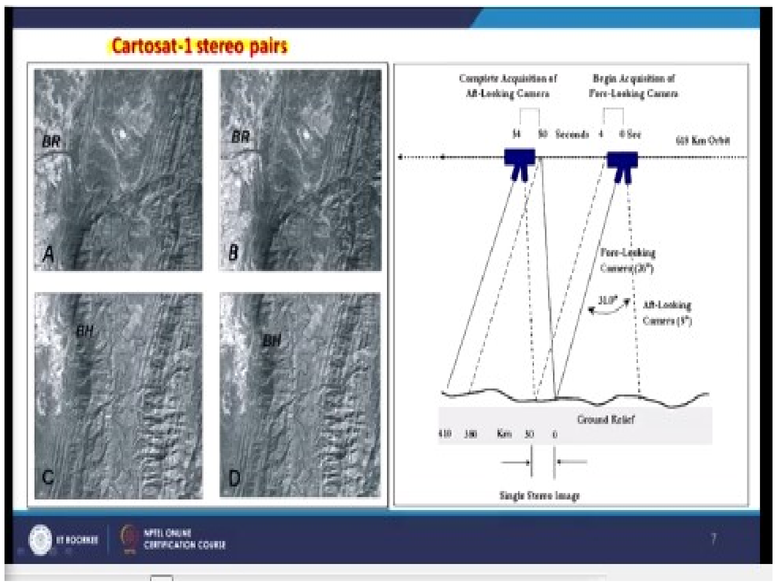

And this is what we did from these stereo pairs of Cartosat for our area of interest and generate a digital elevation models without any problem. So, this can be done many softwares supports these photogrammetric techniques for example, radars which is having a separate extension or shoot which is called photogrammetric shoot. And using that shoot you can definitely generate digital elevation model even using Cartosat data.

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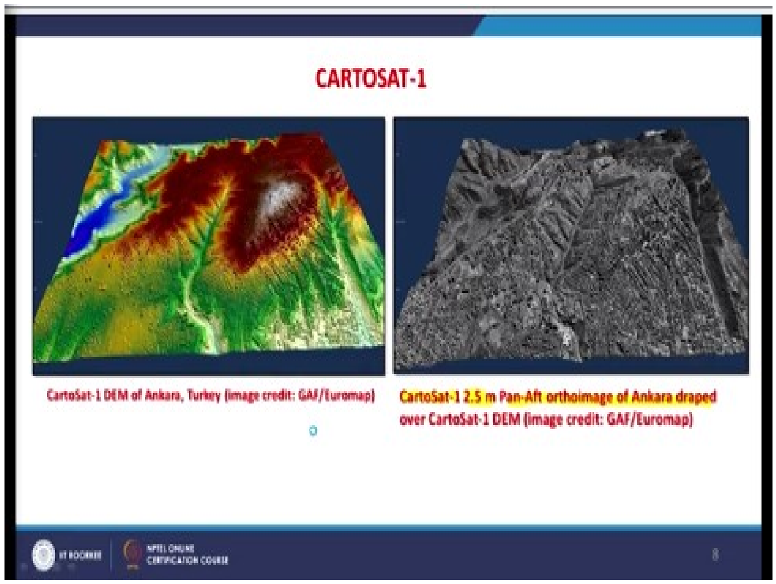

And the same Cartosat data can be used for example here, Cartosat-1 data of 2.5-meter and this Pan-Aft orthoimage is draped over the digital elevation model which was generated by Cartosat of the same area.

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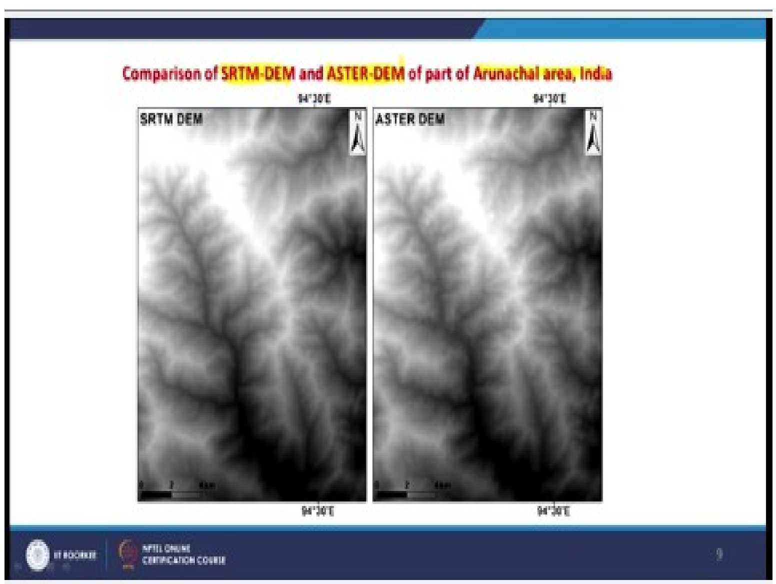

So, likewise you can generate. Now, there is some other data is also available which one can compare with the different areas even they are might be having a same spatial resolution. So, this is what I was saying? That 30-meter spatial resolution in many-many cases except for a very small area and one would like to cover in much detail then one may go for higher spatial resolution.

But otherwise in many-many studies 30-meter spatial resolution of a DEM is quite optimum. Here the comparison is between SRTM-DEM and ASTER-DEM, why this comparison here in this discussion? Because ASTER-DEM is generated based on the stereo pairs whereas SRTM-DEM is generated based on SAR interferometry. That means 2 different techniques were implied for an area like Arunachal Pradesh of India.

And if you visually you compare, you do not see any much difference here. But if it would have been a high hilly terrain like western Himalaya where you are having a snow covered or glaciers areas then this SRTM-DEM may not give you very good results. Because of the problem with the absorptions of energy and dielectric constant and other things related with radar remote sensing.

So, when you download the data and if they have not filled the voids, you may get a lot of voids which would be represented through the no data whereas in case of ASTER-DEM that issue does not come. So, in comparison also we have found that ASTER-DEM is quite good for highly rugged terrain like Himalaya, I am talking about the same 30-meter resolution DEM's from both these techniques, whereas SRTM-DEM of 30-meter resolution may not be good of Himalayan terrain but it is very good for plain areas.

So, depending on your requirements if you are working in a highly rugged terrain then these stereo pair based technique or a stereo pair based DEM will be more accurate than your SRTM-DEM and vice versa in case of plain area. Now, one powerful technique that I have said in the beginning. Before that, we discussed the stereo pair based technique.

And now we are going to discuss this SAR interferometry or INSAR based technique that is becoming really very powerful and very accurate as well compared to other techniques that is why it is very-very popular nowadays. And these SAR interferometric techniques for generating digital elevation model basically started with the satellite which is called RADARSAT.

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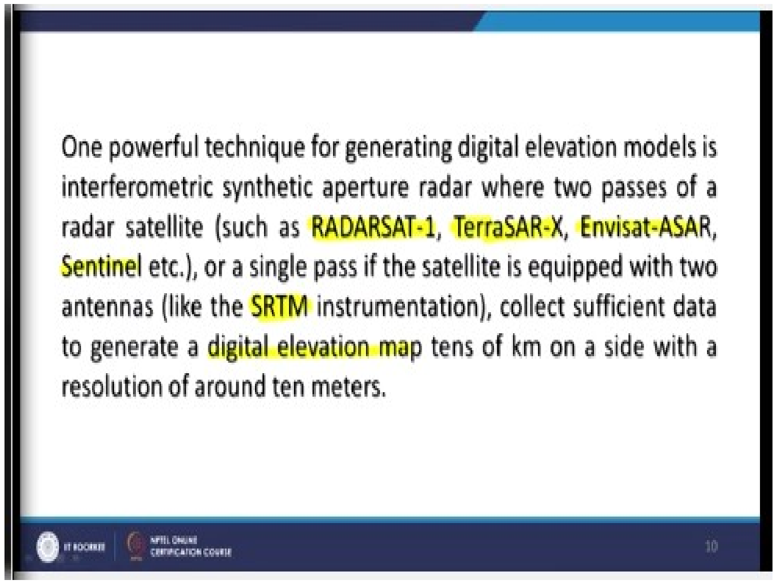

Because that only allow to create a pair not a stereo pair but a radar pair and then later on using this interferometry technique digital elevation models were prepared. However, nobody tried to imply either RADARSAT or Terra or Envisat-ASAR or the Sentinel to generate digital elevation models for entire globe. Only it is started with SRTM (Shuttle Radar Topographic Mission) and later on by this ASTER.

And both of these organizers in which we are involved for these missions or satellites, they developed digital elevation models at different resolutions and covering almost entire globe. So, that really brought paradigm shift in case of availability of digital elevation models at global scale. So first of all, they provided the choices of different spatial resolutions and also different DEM's developed based on different techniques.

So, that way though ASTER-DEM's we have discussed is based on a stereo pair but nonetheless some stereo pair data is good as I have also mentioned for a hilly terrain like Himalaya and SRTM-DEM is not so good for highly rugged terrain and plain area. So, in that way these products are really complementary to each other. So, now there is lot of choices.

And earlier Envisat, now Sentinel data are available and many of Envisat and Sentinel data are available free. So, one can download the data i.e. the radar pair and can imply this SAR interferometry technique and can develop a digital elevation model of a relatively very high resolution.

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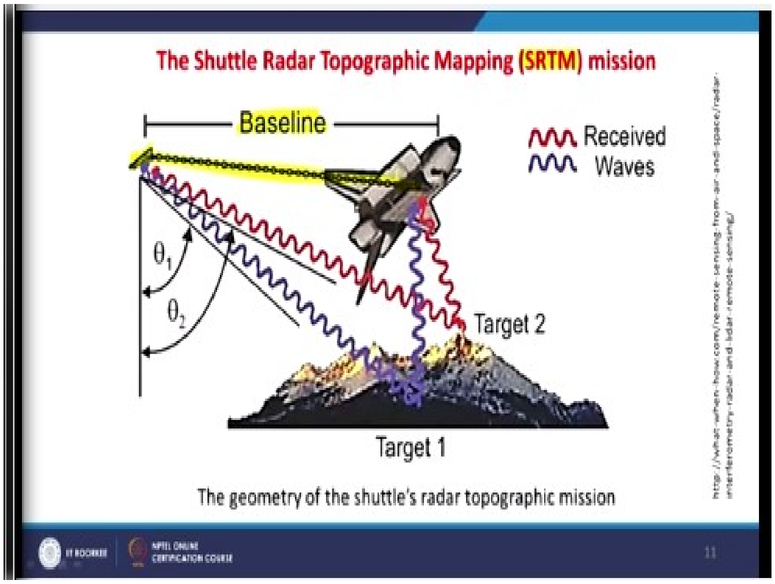

We have mentioned many times or discuss this SRTM i.e. Shuttle Radar Topographic Mission; it was a mission not a regular satellite. And the best innovative part was that, the baseline is a big issue in SAR interferometry. So, they had a 60 feet shaft which allowed to create a baseline. So, there were instrument here and there were instrument here and both were collecting the radar data or the radar information.

And that means the same time with a fixed baseline because baseline was connected with a shaft with 2 instruments. So, with fixed baselines with 2 different angles, the same area was covered at the same time and that allowed to generate digital elevation model for almost an entire globe relatively easy way then as compared to other techniques.

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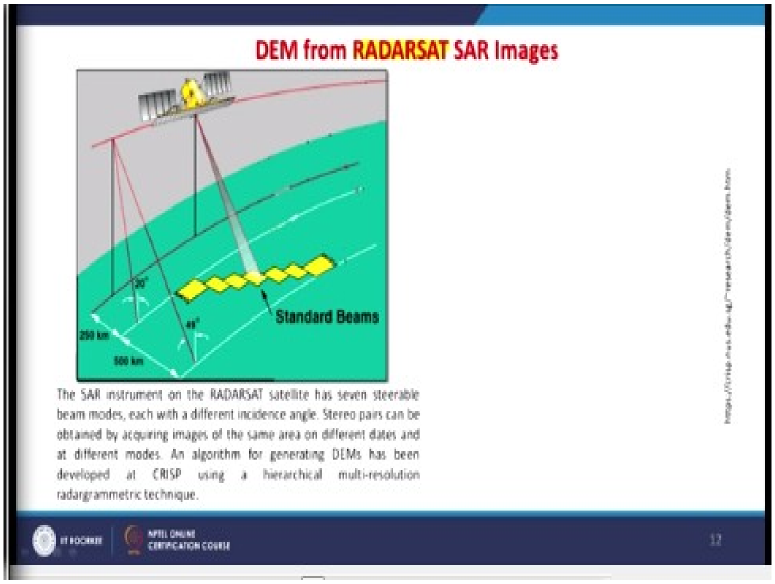

Similarly, (()) (17:15) RADARSAT was a regular satellite and therefore, it did not carry that shaft of 60 feet. So, you have to wait for another orbit to acquire the data adjacent orbit. And sometimes the gap used to be of 35 days and that means in these 35 days a lot of ground changes or weather changes can occur. And these changes will ultimately may be reflected in form of errors in these products.

So, these were the problems but that problem was like in case of Cartosat, stereo pair data acquisition, the problem of changing environmental conditions or metrological conditions were resolved, similarly in case of a shuttle radar topographic mission that was resolved. But in a conventional way of collecting data with 2 different angles of the same area either using RADARSAT or a SPOT or any other satellites. These changes in weather conditions brings lot of problem, 35 days' time difference is too big.

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So, like here this we call as power image, there is images in microwave region or radar images and say a stereo pair or just a pair I would call. And when you can imply these 2 radar images and can generate a digital elevation model implying SAR interferometry technique.

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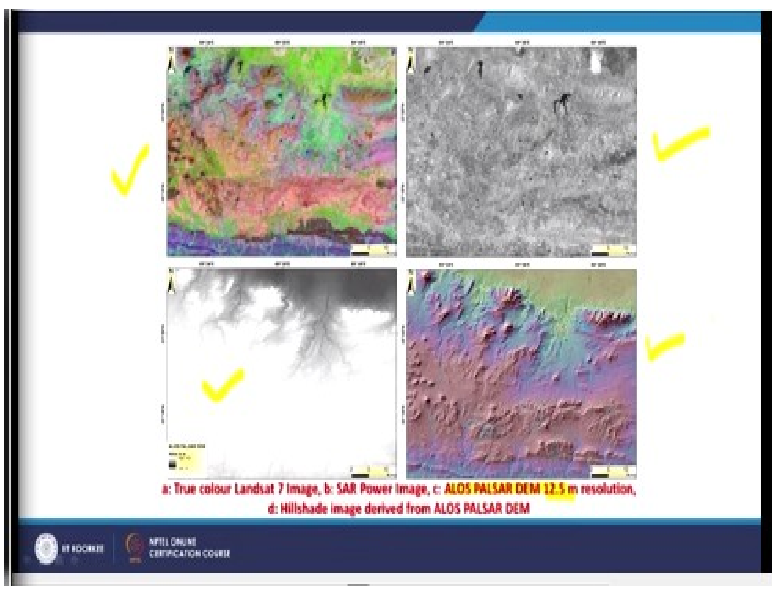

Similarly, we also employed like instead of RADARSAT we employed a ALOS-PALSAR-DEM could generate a 12.5-meter resolution. And this is from Gujarat area or Kutch region. So, as you can see this is digital elevation model of the same area, the top left in this is false color composite, this is the power image that is the radar image and then you are having digital elevation model generated with a pair using SAR interferometry technique. And you are also seeing a shaded relief model or hill shade with colors.

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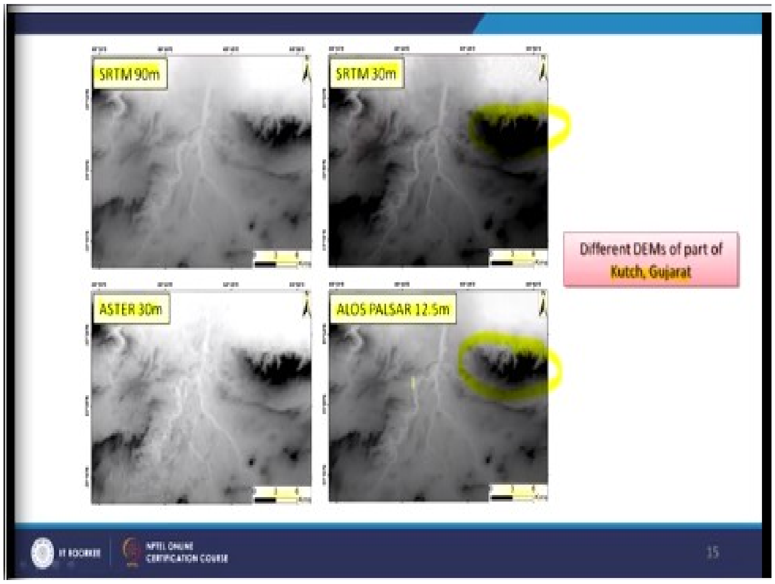

Now, if you look the terrain with multiple spatial resolutions DEM of the same area you may notice the changes in the information content or like here this is SRTM 90-meter of the Kutch region Gujarat, this is SRTM of 30-meter, this is ASTER DEM or GDM of 30-meter. And then ALOS-PALSAR is 12.5-meter. So, you can see differences like here in 30-meter you do not see the details as much as details you see in 12.5.

So, I would repeat that if there is a requirement then only one should go for higher and higher spatial resolution either for satellite images or for digital elevation models. If your requirement can be fulfilled with relatively medium range spatial resolution like 30-meter then one should resort for 30-meter. Because in case of 30-meter, there are various choices are available but in case of you go higher and higher than the cost may come.

Otherwise 30-meter spatial resolution DEM's are available free of cost, just you have to download from different sites. Now another technique which we have touched by discussing different methods of generating digital elevation models which are remote sensing based.

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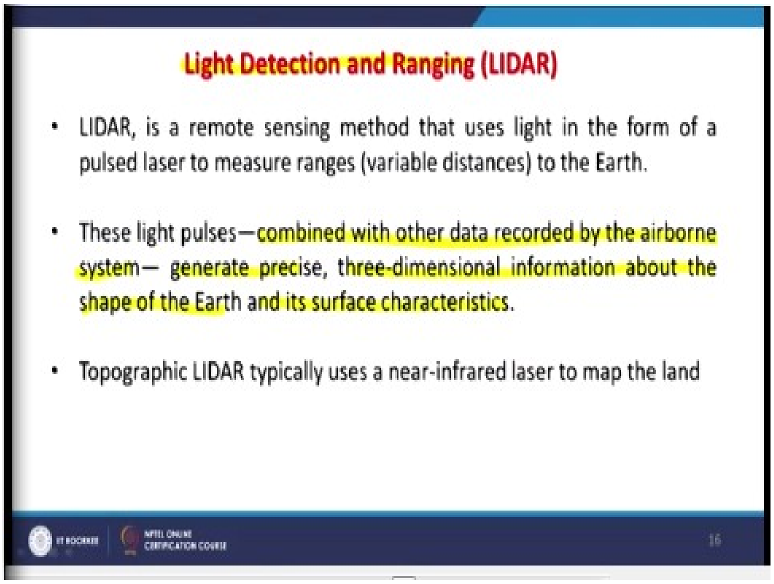

So, this is a new development which has taken place in last 7-8 years that is the Light Detection and Ranging or in short we call as Lidar. So, again this is a remote sensing method which uses light in form of a pulsed laser in 2 major ranges, variable distance to the earth when the survey is being done by Lidar you do not basically see the light. Because it is in the form of pulse just a very short illumination.

And these light pulses combined with other data recorded by airborne system, generate precise 3-dimensional information about the shape of the earth or its surface characteristics that is basically a digital elevation model. Earlier it started with ground based radars, it used to be installed on a vehicle and thrown. Now the instrument is going airborne or spaceborne.

Now, topographic Lidar or generating a digital elevation model, basically, it uses a near infrared laser to map the land, not really visible light but a near infrared because it has to cover a large distance from space to the earth. So, it has been found that infrared laser is better when distance is involved then simple light. Now, I would show you some examples of these Lidar products.

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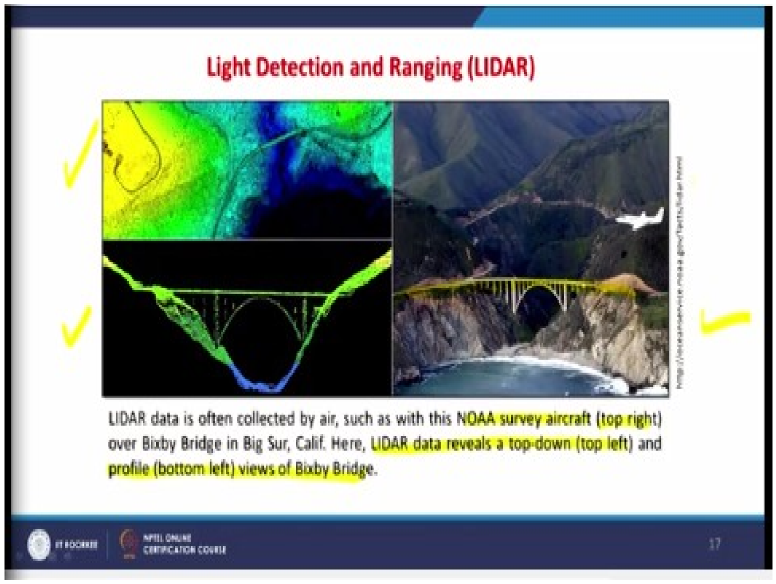

And like here you are seeing that the top left image is just that Lidar image from top or nadir viewing radar image. And whereas in comparison you can also see a visual image in profile form and a profile generated from your Lidar image. So, this top left is basically Lidar which reveals the top down whereas the bottom is the Bixby bridge which is seen here.

And here definitely top right but you see a survey on the ground which has been done when a photograph was taken. So, in real the right one is the visible part whereas the left one and bottom left is your based on the Lidar. Here, from whatever the distance you are standing you can also measure the distance as well as you can map the things as shown here.

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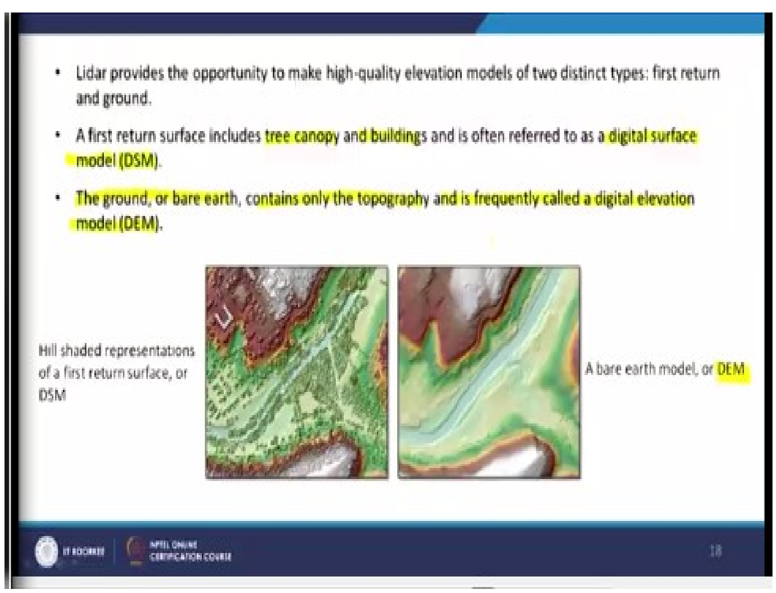

So, basically Lidar provides opportunity to make high quality digital elevation models because the number of points or it is called point clouds which it collects is enormous compared to any other technique. So, from a SPOT height point of view that density of points is very-very high. And while discussing interpolations using survey topo sheets point heights mentioned that when you are having a high density of points, observations or measurement, obviously your digital elevation model is going to be very accurate because this is what your interpolation techniques require.

So, as you know that in this Lidar technique, it first generates the DSM i.e. Digital Surface Model, which we have also discussed in earlier lectures. So, first a digital elevation model, now by masking that surface features sometimes as per requirements, we can remove that surface features and can get a bare surface and that becomes your typical digital elevation model.

So when the trees canopy and buildings is included in our data, then it is called the DSM but when it becomes the bare earth or bare ground which contains only the topography then frequently called or better known as a digital elevation model. So, here on this image what you are seeing the hill shade representation of first return surface or DSM and when these features were removed like tree canopies and buildings or any other human made structure then you get a pure DEM (Digital Elevation Model) or the typical digital elevation model which we know. So, you can see the major difference between the DSM on the left image and DEM on the right image. So, this DSM term basically has also come in this domain which is the Lidar-1.

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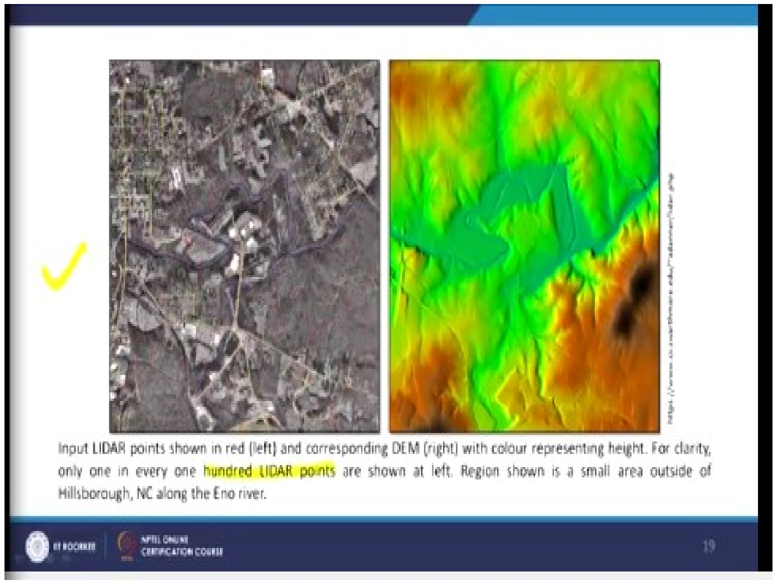

Also here if you see very carefully, you would find a lot of red dots which are present on the left image. These are the nothing but the points which have been collected, these are the hundreds of Lidar points or we call as point clouds. So, when density of input points is very high, you can really generate a very high resolution, very accurate digital elevation model and this is what it is shown on the right image.

So, that is why Lidar is becoming very-very popular but we do not have any product which is available free of cost based on the Lidar technique. Otherwise, it is a very powerful technique to generate digital elevation models or a 3D surface even on the ground at very high resolution and very accurately implying the Lidar technique.

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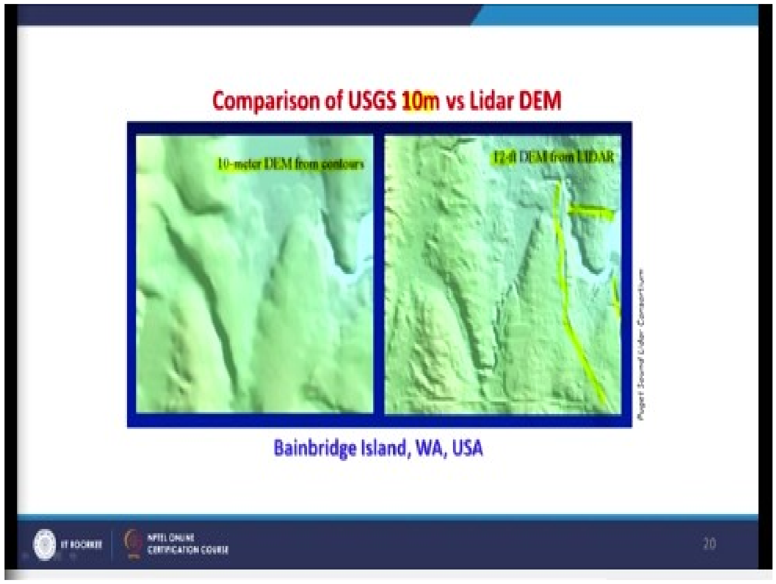

Now if we compare like 2 digital elevation models generated using different techniques like this is called 10-meter resolution, so whereas this is 12-feet meter resolution, this is 10-meter resolution of the same area and this is based on the contours on the left image whereas this is based on the Lidar. Lidar, as you can see can bring a lot of details in this one. Now only problem which you might have observed that because removing the canopy and buildings that means creating a bare surface for a typical digital elevation model in case of Lidar may not be always possible or may not be always complete.

And that is why you are seeing some human made structures even in this bare Lidar DEM. So, that may be one of the problems associated with Lidar-DEM otherwise it can produce a very high resolution digital elevation model without much big problems.

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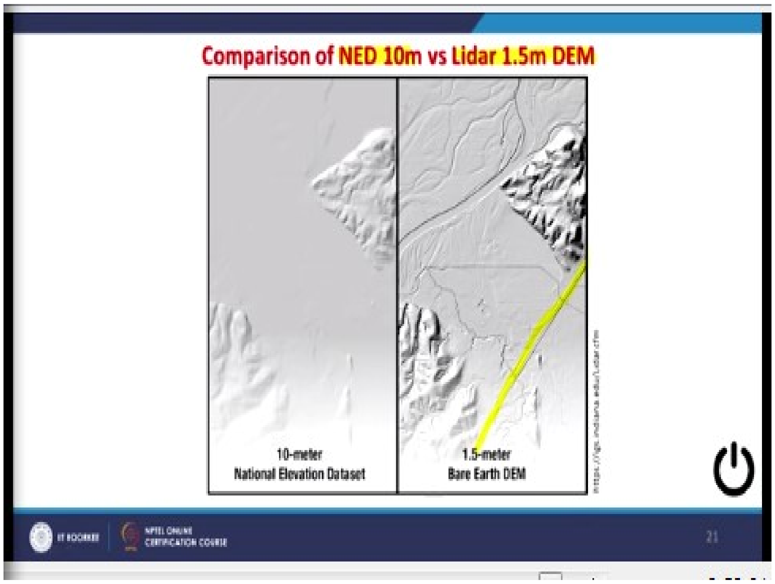

Another example here is, this NED a 10-meter, these products are not available at global scale, only for US. So, this is 10-meter resolution and this Lidar at 1.5-meter resolution and you can see that what kind of details it is providing on the right side image compared to a 10-meter resolution and which is not based on the Lidar either the NED-1.

So, this kind of detailing is provided however as I have mentioned that even it is very difficult to remove all surface features or manmade structures or natural canopy completely from that surface. So, still it is not qualifying as a typical digital elevation model but it is in between a DEM and DSM. To some extent the surface features have been removed for example in this one but still they are many their remnants are still visible clearly in a very high resolution digital elevation models.

So, this brings to the end of this discussion i.e. the second part of generating digital elevation models using remote sensing based or some like interpolation based techniques. And next part we are going to discuss also the thermal remote sensing based technique to generate digital elevation models but for time being, thank you very much!