Geographic Information Systems
Prof. A. K. Saraf
Department of Earth Sciences
Indian Institute of Technology-Roorkee

Lecture-51
DEMs derivatives-4

Hello everyone! and welcome to a new discussion which is part 4 of DEMs derivatives. This is the last part in the derivatives. But we will keep discussing about the applications of DEM and also few more derivative. But we have categorized them. So, this is in that sense. It is part 4 and derivative. As you know that DEM is a raster representation and which represents a continuous surface. So that is why, it is also continuous data contrary to like contour or point data which is discontinuous or discrete.

So here, we are having continuous data. And currently not only we use or reference to the surface of the earth but digital elevation models of Mars and Moon surface are also because there are many satellites which are orbiting around these bodies like the moon or planet like Mars. And they too have created 3D digital elevation models for the surfaces as well. So, this is not only the surface of the earth but DEMs are now available for another surface is also.

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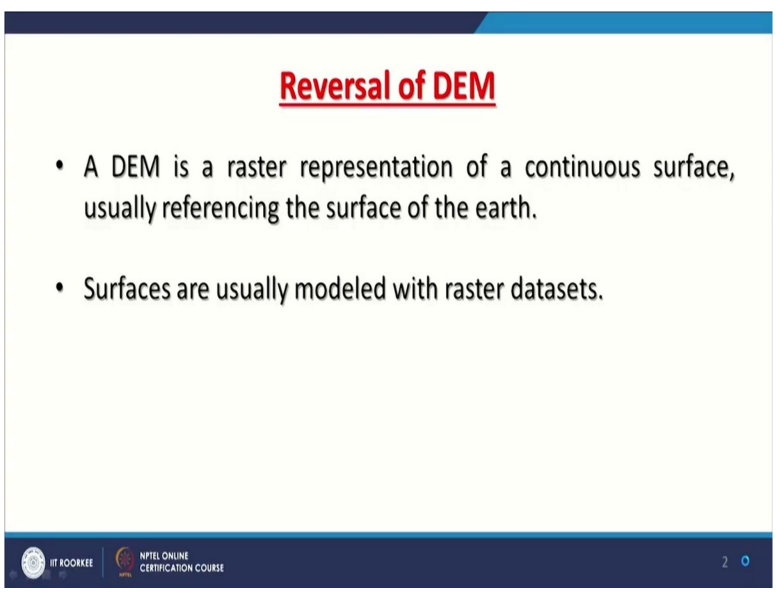

Now these you know that they are modelled because that is why in the name itself; the digital elevation model. So, this is not the reality. The real world is 1:1 scale so this is scale down. Therefore, we say a model or an abstract form of reality. So here, these terrain surfaces undulations whatever present on the surface of the earth, they are modelled one. They are not the real one. Why model because each cell is representing a single elevation value.

And if it says 30-meter resolution that mean for 900 square meter elevation, we are having just one elevation value. But if terrain is highly rugged like Himalaya, then within 900 square meters, you can have varied digital elevation values but they all have been average down and a single elevation value has been assigned again that cell. So that is why, it comes under the category of model because it is not the real world. It is the abstract form of reality which is representing the terrain surface.

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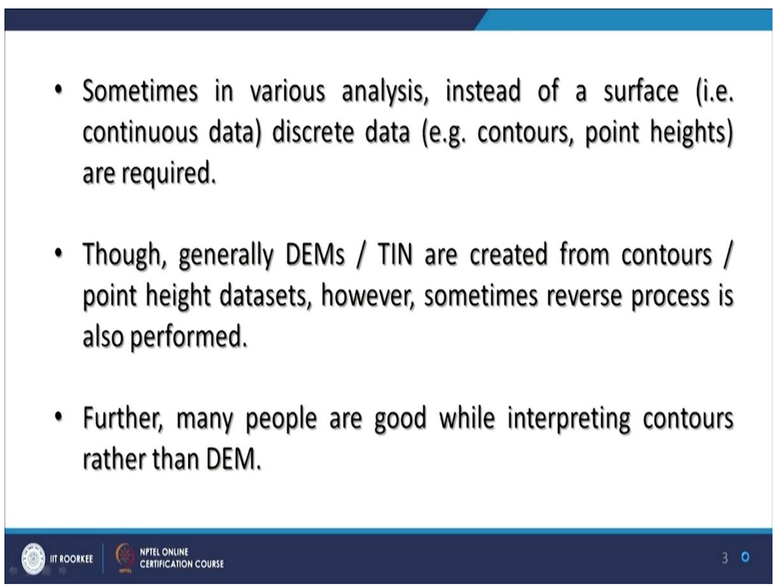

Now also we know that in various analyses instead of using continuous data, still some people prefer using discrete data. Even for ourselves, sometimes we have to go back from continuous to discrete. Why I have used word go back because I understand that the continuous data is a hierarchy. In hierarchy, it is on the top like TIN model also.

But point data or line data or polyline data or contour data are the discrete data. So, in that sense, they are not in hierarchy in the top. They are in the bottom like point but sometimes for different applications, we have to convert or create contours using a surface so that we will be discussing for what purpose, we are and how to do it on GIS software. So, as you know either DEMs or TINs are created, though they are created either from point height datasets or contours but sometimes we have to reverse the process.

And still many people are very good of understanding countries rather than DEMs because senior people those who started initially with contours and studying the contours in topographic maps, they are still find very convenient to use contours rather than DEMs. Working with my senior colleagues several times I have found that whenever I have showed digital elevation models to them, they were very uncomfortable and they said can you produce this thing in form of control so then I will understand.

So, for such people also because some time they are the decision makers; the senior people are decision makers and their understanding has to be very good about the terrain, otherwise the decisions might be wrong. So, whatever they are asking, you should be able to produce the products according to their choices or preferences.

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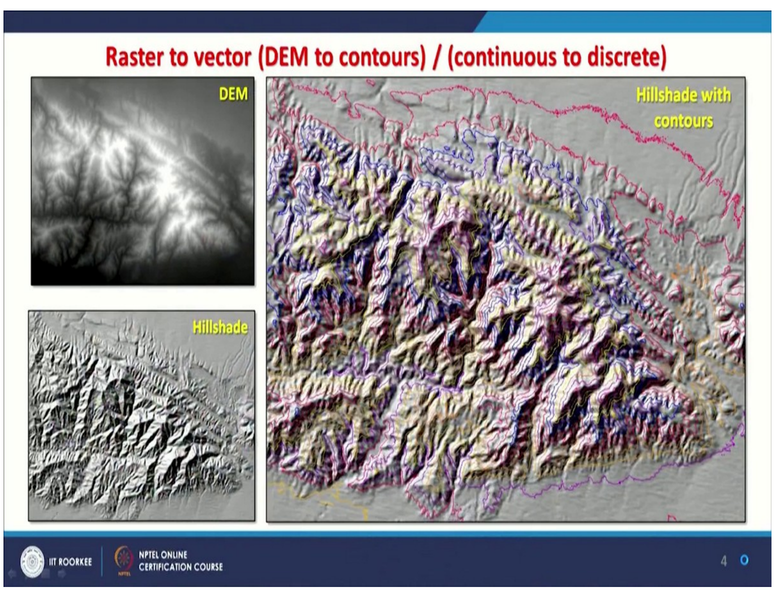

Like here what I am depicting, here is in the corner what you are seeing a digital elevation model which you can see that the digital elevation model is here. Then in the bottom left, you are seeing a Hill shade; that is the shaded relief model derived from the same digital elevation model. These two images or these two datasets must have been seen in various presentations or lectures of this course so this is that same dataset.

What is on right side; the bigger one. What it is showing is the hillside with the contours. So, what I have done? I kept the hillside in the background and derive the contours because I am having a continuous surface that is my digital elevation model. So, declaring to the system that I want contour interval starting from here and with this interval. So, whatever the intervals I decide, whether 1 meter or 10 meter or 20 meters because remember one important thing here is that though spatial resolution might be 30 meters; that is in horizontal scale.

But vertical scale; that is the z units is in meters so maximum I can drive contours of 1 meter interval, that is you know the best possible. If suppose this digital elevation model might have been prepared using contours of say 20-meter interval. But after creating a digital elevation model, now I can create contours even at 1 meter because the least count in my vertical scale of z or for elevation is 1 meter.

So that is another advantage of how to you know get more because for small area, even 1 meter contour will matter lot. But for a highly rugged terrain, 100-meter contour may create clattering in your maps. So, depending on the unevenness or ruggedness of the terrain, sometimes we change the density of contour. How would you do it on a standard GIS software for example in ArcGIS but I am sure all the software support some. I am having experience of ArcView, Elvish or other software, they also support but you have to provide elevation grid; that is the input raster.

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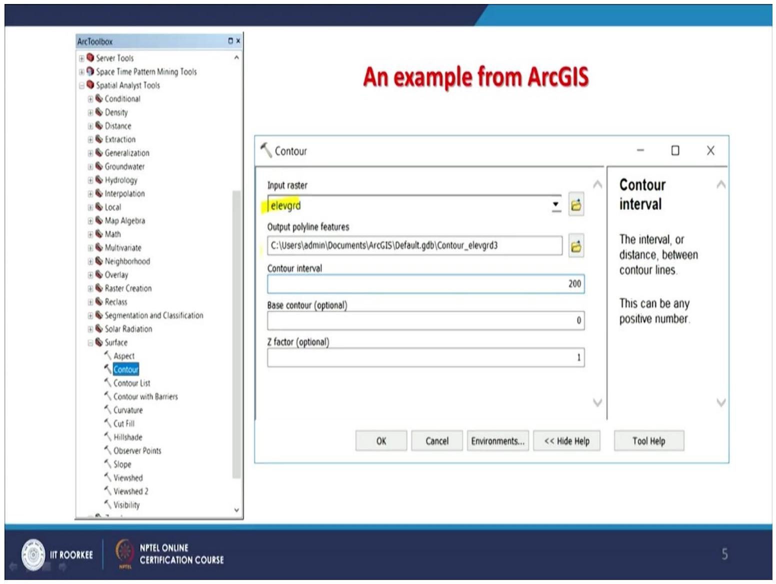

You have to provide where it will be stored and then contour interval. So here in this example, I have taken contours interval of 200 meter, you can take even 1 meter and then base contour, I said Okay! Start with zero, does not matter and then of course the z factor. In many-2 such options z factor will be keep coming. So that accordingly depending on your data set because the example which I have taken is all in meters. So, I can keep z factor 1.

And once you say Okay! You can derive contours as you have seen in this right picture. Now another advantage is sometimes I am interested only in one particular contour or one particular contour I want to derive, rest I do not want because I might be looking for my route alignments; for road alignment, especially for rail track alignment. I might be looking a single height contours for my power channel or for canal network in hilly terrain.

I might be looking a route which is having the same elevation; that means nothing but it's a single contour.

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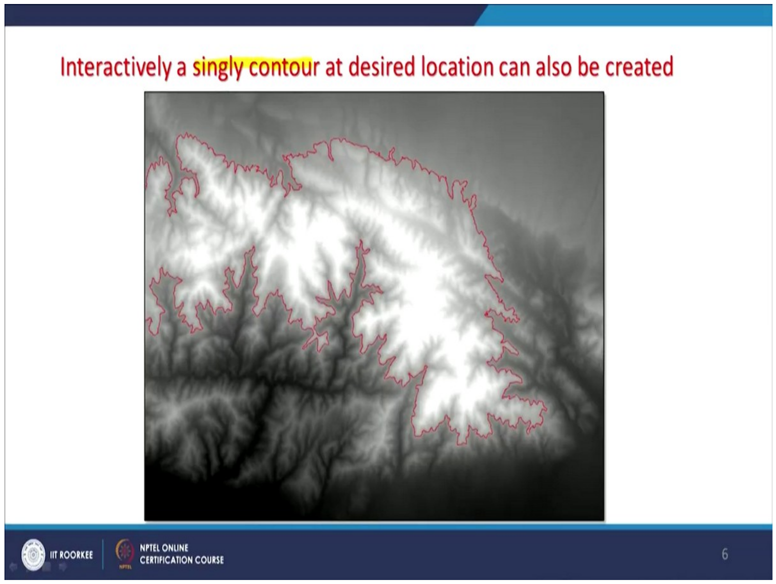

So single contour can also be derived. So instead of interval, I would use some you know and not give the interval. Interactively also, the tools are available in the software that wherever I will put my cursor and click, I get that Contour or you can just put the value that I am looking the contours which is having this height or this elevation or this value. And accordingly, it will be drawn. Because in real projects, many times you are looking various things. You want to derive various things from one single digital elevation.

So, all this is possible. Though as I have said, this is a backward kind of process; from a continuous data, I am going for discrete data. But for certain project, these things are very-2 helpful. So, such information like single contours becomes useful when on spot decisions are being made. Because nowadays it is possible to carry even a small version of GIS on a laptop or a full version and where the decisions are being taken on the field, I can derive the products immediately there also.

Now this was from continuous to poly-line. Now continuous to points also; that is the lowest in the hierarchy. That is sometimes also very much required for various kinds of comparison, various kinds of clustering studies and comparing with some point distribution with other point distribution and so on. Some examples, I will just so you from my own domain that first, points are generated.

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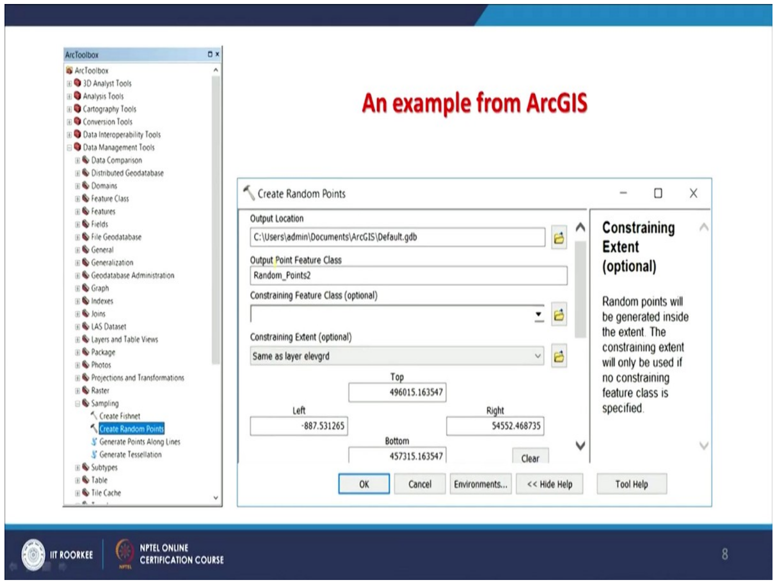

So, random points are generated for that extent for which I am having a digital elevation model. And then later elevation; that is the z value would be added or in some software language like in ArcGIS, it is called 3D point; 3D means that attribute is having z value so then it becomes a 3D point. For example, here what we are seeing that this is output location. Random points are there and I have declared that how many random points I want? What should be the extent of the data and once I say Okay! I get.

So, this random points tool is available in data management. I tell you that this random point tools random points generator is very-2 useful. You can have the creation of random points. You can select the random point and they are very useful in various kinds of analysis which involves the point data. So, this is very-2 important from that point of view.

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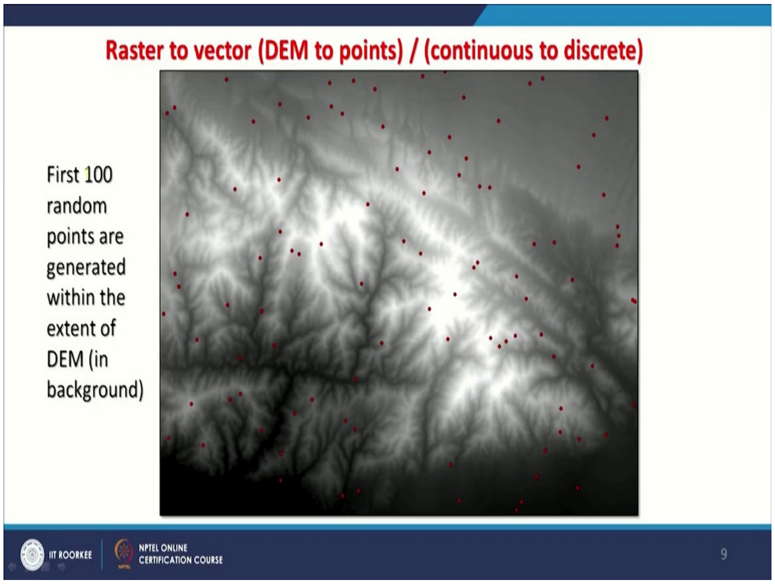

Likewise, I have created now random points and then we collect the z value from the digital elevation model which is shown in the background. Then my point becomes a 3D point basically. So, like here 100 random points are generated within the DEM extent. Extent, you have always given. So, if you want to perform on say this digital elevation model then extend would be given or you can change also this extent or the area of interest.

But generally, from which digital elevation model I want to pick my z values, the same extent one should select.

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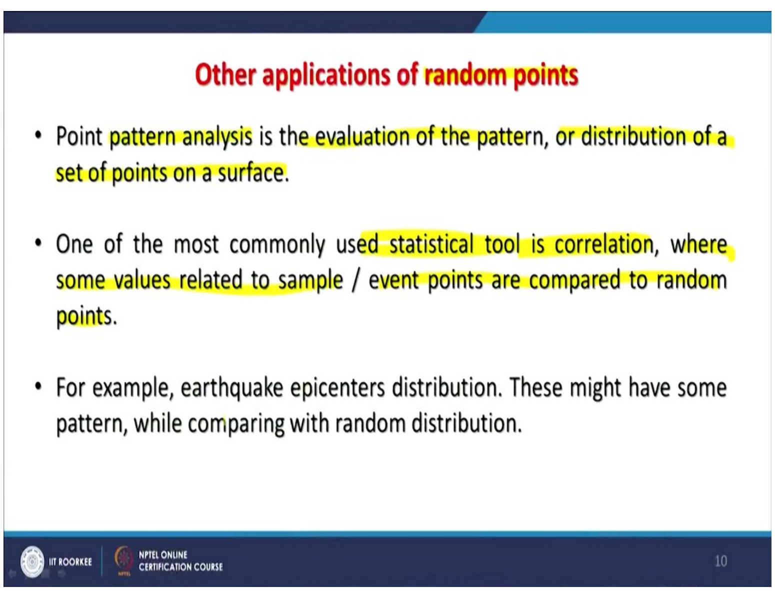

Now what are the other applications of random points? That points pattern analysis; this is very-2 important for many kinds of analysis. Like I want to compare the earthquake epicenter and when I want to see how these number of earthquake epicenter are distributor randomly; whether there is some pattern or not. Or any kind of data collection or any kind of checking also, these random points become very-2 useful.

So based on this analysis, it is always very useful for various applications. So, this point pattern analysis basically is the evaluation of the pattern or distribution of a set of points on a surface. Now these points which we have collected here for example 100 points, statistical tools are used to correlate with other point distribution within the same extent where the sum values related to the sample even points are compared to the random points.

So, as I give the example if I am having the distribution of earthquake epicenter location then I can try if I am having say 100 epicenters, I can create random 100 points and then can compare based on statistical analysis and basically this statistical analysis involves the distance between among the point. So, if the distance among points is less, that means they are having some pattern but if they are randomly distributed then the distance is going to be quite large.

So, for example; I have already given this example that earthquake epicenter distribution. These might have some pattern while comparing the random distribution. While I expect some pattern because generally, they are located along a geological fault line or structure. So that is why, this can be compared with the random distribution, very easily.

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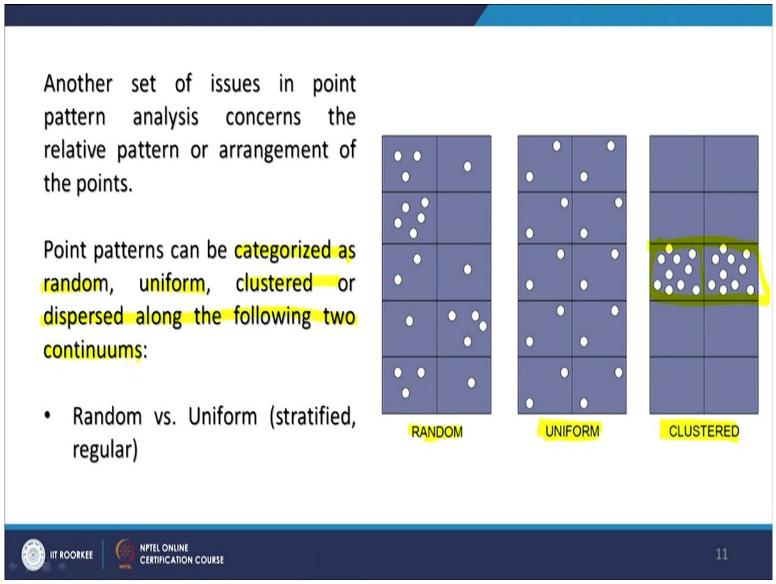

Now another set of issue which can be solved by using this point pattern analysis which is the concerned the relative for pattern or arrangement of pattern. For example, here same numbers of points are taken in all three examples in a schematic. The first one is the random point. So how randomly these are distributed whereas this is the uniform; that means in each box, there are two points and there is a pattern, there is everything fixed.

So that is why, it is uniform or you can say organized distribution. However, this is clustered distribution. That means only into blocks, here we are having all these points which are either randomly distributed or uniformly distributed. So, like cluster, there can be a linear arrangement or distribution also. So, immediately then things can be compared using the distance among those points.

So, point patterns can be categorized as a random, uniform, clustered or dispersed along the two continuous or two continuums. Now the randomness vs uniform; that is stratified or regular, we can decide that. So, any distribution of points can be assessed comparing with random distribution. Clustered or dispersed; that too, we can do this kind of distribution. So, two continuums can be done. Whether the points are uniformly distributed or randomly distributed, whether the points are dispersed or clustered.

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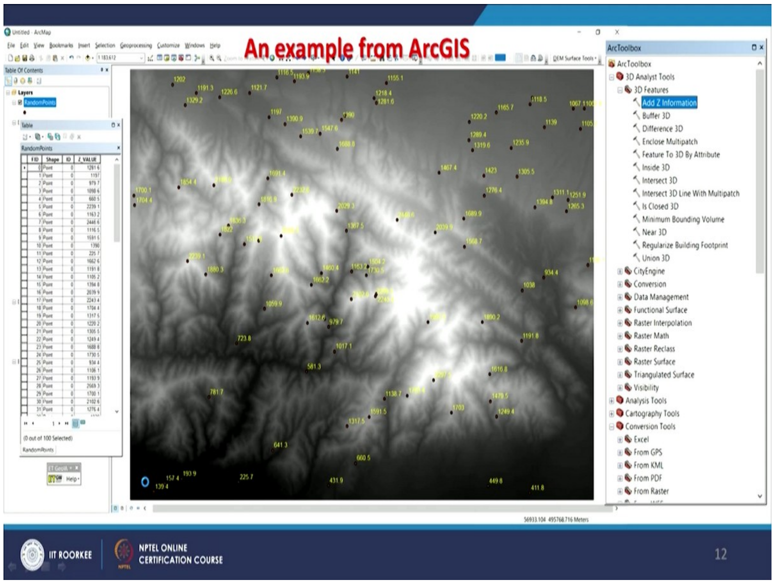

So, all these kinds of analysis can be done. Like for example I am taking here, this is as you can see that add z information. So, I am creating a 3D points against the distribution of these random points which I have generated in number 100 and then their z values are added as you can see here. Generally, when you create because attribute level of point data will be populated with the z value collected from the digital elevation model which is in the background. So that creates all our points as 3D points.

3D again, I have said that means they are carrying z value also. It is not necessary that all point will always carry z values but if you are having points and same time, you are having corresponding digital elevation model so for some applications you require z point, you can definitely collect using such tools available in standard GIS software.

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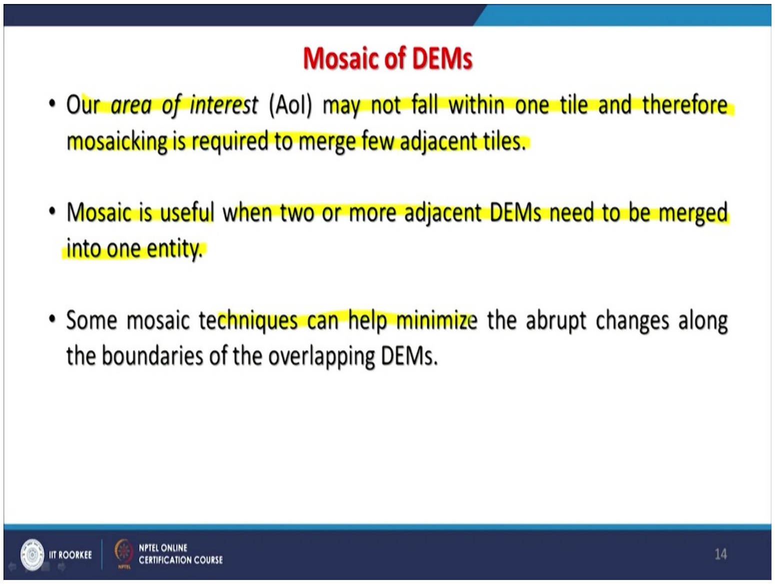

Now another related thing is while handling digital elevation models, that sometimes you have to create mosaic of the DEMs. Now question is why mosaic we should create? Mosaic is created because lot of free DEMs which are available through net, they are available in tile forms. Generally, you will get 1-degree tile or 5-degree tile. 1 degree tile means 1 degree latitude and 1 degree longitude, that much area, roughly 110 *110-kilometer area will be represented by one tile if it is 1 degree.

Now, your area of interest will cover in 4 tiles. So, individual tiles are available. You have to download and create a mosaic of these tiles. But interestingly some sites are there which are using your area of interest as polygon or extend which you give in terms of latitude, longitude and that site will create a mosaic of these individual tiles and will give you a big Mosaic DEMs. But the problems are that because it is easy to download individual tiles but if there are 10 tiles are involved, the size of the file will become very large.

And therefore, sometimes it may be difficult to download from net. So, always it is good to download these tiles because this is how the data is kept nowadays in form of tiles for global scale data and then you can mosaic these tiles. So how they are mosaics basically? That the mosaicking merges basically, adjacent multiple existing DEMs tiles into an existing DEM or raster dataset. If you have a raster dataset fine, if you do not have, no problem. 4 times can be merged and 1 single file can be created.

So, it is required because as I have already mentioned that many global DEMs are available in tile forms. For example, here what we are seeing 4 tiles. So, employing this mosaicking tool, I can create a single tile without any seam because first this global scale digital elevation model was developed and then tiles were created and therefore when we create again mosaic, there should not be any seam.

Otherwise, it will become less reliable or useful data. So, a seamless mosaic of digital elevation models can be created even if they are available in tile forms. And generally, all these downloadable digital elevation models available from various resources or internet sources, all are available in tile forms. No problem! It's not a problem at all. It just requires a few more minutes to create a mosaic and then you can use it. So, our area of interest must be known to us and then only you get the appropriate tiles and then you can mosaic.

So, our area of interest may not fall within 1 tile or therefore mosaicking is required to merge few adjacent tiles. This is the very common step and common problem also because you may find if it is very small area, you may find that it is falling in just 1 tile but if it is a little larger area, you may find that it is falling in minimum 4 tiles or 8 tiles or 20 tiles, it does not. It depends on the size of area of interest.

So, mosaic is useful when two or more adjacent DEMs need to be merged into one entity. And some mosaic techniques can help minimize the abrupt changes that means seamless. So, in case of satellite images, creating a seamless mosaic is very challenging because two adjacent satellite images may not be representing the same date data of the same year. And therefore, because the atmospheric conditions might change from day 1 to day 2 of these two adjacent tiles of a satellite image then seamless mosaic becomes very difficult.

And that is why you see on Google Earth, many times if you zoom it and you encounter a boundary or a seam, that is the reason because two adjacent scenes are having different ages or different dates of acquisition. And this is also there because each satellite is having its swath width; that is the fixed. Like for example NOVA AVHRR which is having roughly swath width of 2800 kilometer. So, one strip of 2800 km is being scanned every time whenever the satellite is orbiting around the earth.

Whereas if I give an example of ICONOS which covers only 11 kilometers strip of the earth and therefore if my area of interest is very large, that means I have to get lot of these adjacent coverages or adjacent scene of ICONAS to create mosaic. And when I will do it, I will have problems because these strips or since may be representing different dates. It is highly likely that they will be represented different dates.

And in mean time, the atmospheric conditions might change and it becomes very-2 difficult to create a completely seamless mosaic of satellite images but it is rather very easy to create seamless mosaic of digital elevation model.

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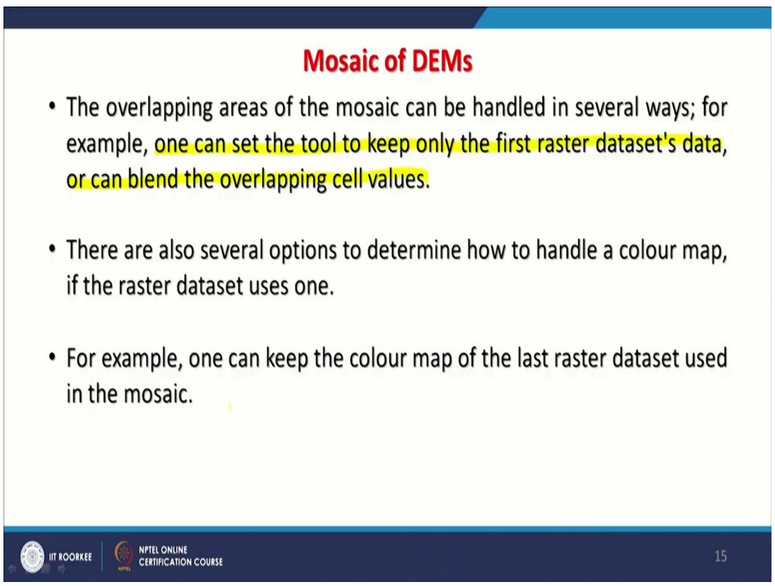

Now these overlapping areas of mosaics can be handled in several ways. This is mainly true in case of satellite images that one can set the tool to keep only the first raster data sets or can blend the overlapping cells. So, in case of satellite images, it happens that there are overlapping so you can choose by creating these mosaics. And there are also several options to determine how to handle a colour map because these satellite images you might be handling as false colour composite.

So, there are also, colours can also be manage and you can say that whichever on the top, all the scenes should follow that colour scheme or that colour map. So, accordingly things will be done. But in spite of all these options, still it is very hard many times to create a completely seamless mosaic of satellite images. So, different advanced techniques are also there but still no technique is yet perfect to create a completely seamless mosaic of all satellite images because of different dates, they have been collected.

Now another exercise which we keep doing in our handling of digital elevation model that is creating is subset or a clip or extracts of DEM. So, this like for satellite images also, even point data, even for line data we have to create a subset. So thus, there are tools creating subset of raster, creating subset of vector. So, what basically requirement is that you should have your area of interest in form of a polygon.

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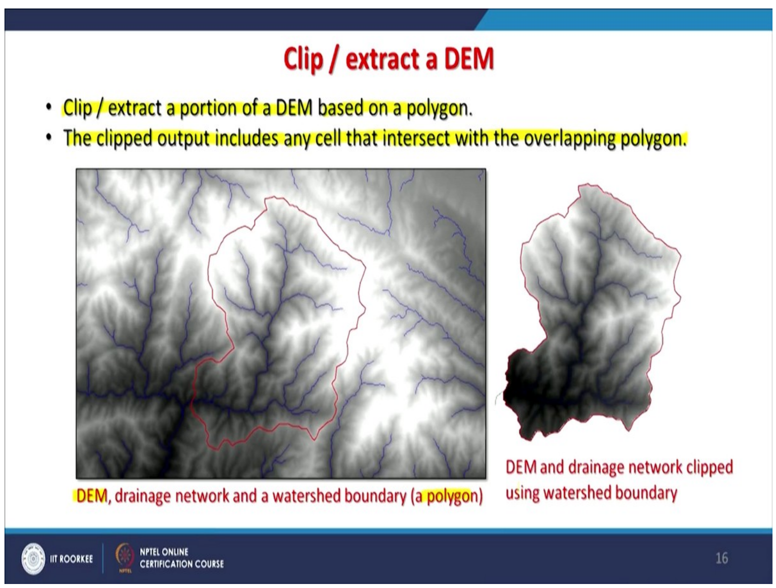

Therefore, clip or extract of portion of a digital elevation model or a satellite image or a point data or a polyline data or even a polygon data, you need a polygon. That's polygon can be a district boundary, can be a country boundary, can be state boundary or can be a hydrological round like the watershed basin or catchment. So, this polygon has to be there, based on that we can extract or clip or can create a subset of a digital elevation model.

So, this clip output includes any cells that interact or intersect the overlapping polygons. For example, here in most of the examples I am using the same digital elevation model throughout which I started in the beginning so that you become familiar because every time if I change digital elevation model, things become unusable. So, I am keeping almost constant the digital elevation model. Now here what you are finding that the red one is the watershed or hydrological boundary which I am taking.

My target is to clip or create a subset representing the digital elevation model only for this watershed. So, it is not a problem. What I need a DEM and a polygon boundary. And of course, I am having drainage network and other thing so that I can clip separately also and this is what I have done. So, DEM and drainage network has been clipped using watershed boundary. So, two examples; one is clipping a raster; that is our digital elevation model and clipping or creating a subset of drainage network that you are also have.

So, polyline, point data, polygon data or raster; whether image or a DEM or grid, for any such data this subset can always be created except one, that is subset of a TIN. Subset of TIN can never be created. So, remember this thing that is the limitation there.

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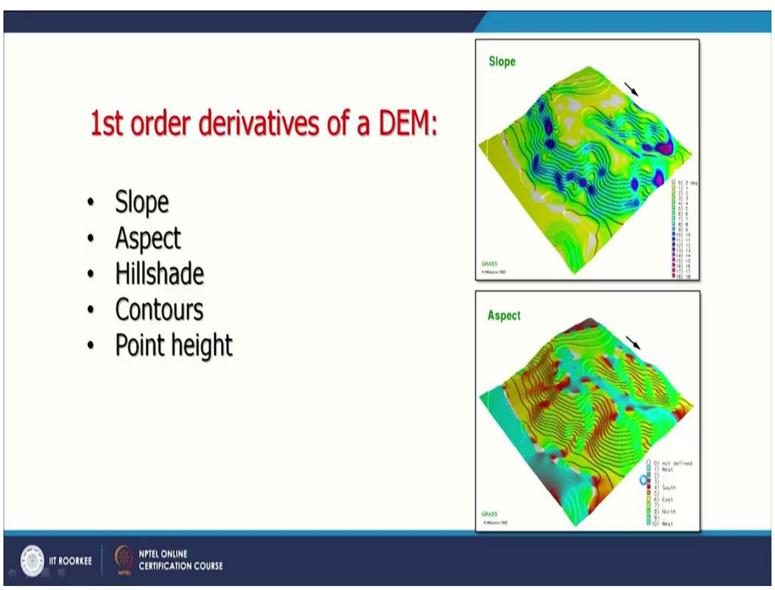

Now the DEMs and derivatives which we have been discussing, what we have completed so far is the first order digital elevation models or primary derivatives also. Some people would like to classify like primary, secondary, tertiary but if I say first order derivative then among them is the slope, very common one then I am having the aspect. And then Hill shade; these are we can put them as first category.

Contour also that is discretization. It's a first order derivative. Point heights; creating 3D point kind of thing.

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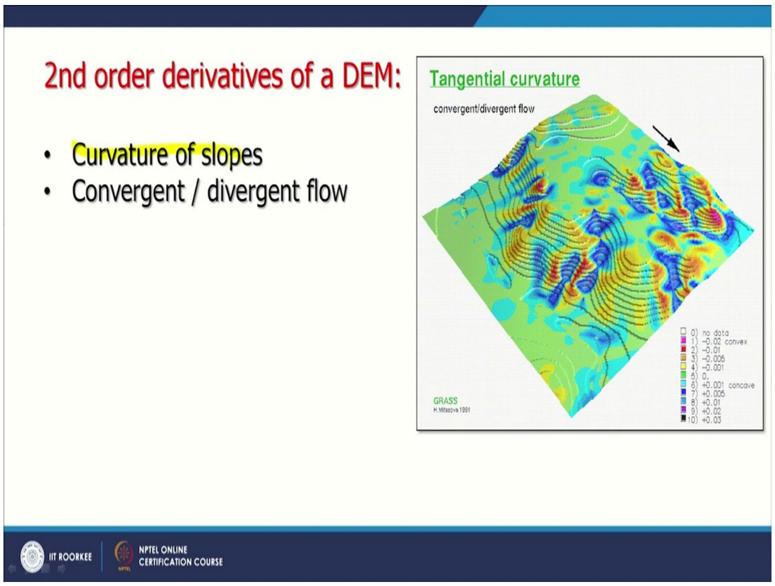

Now among this second order derivative, we have already discussed few of them like curvature of the slopes. Different types of curvature; total curvature, standard curvature, convex, concave. All these curvatures we have discussed. Then we have also convergent and divergent flow. Such analysis is useful from erosional and depositional point of view.

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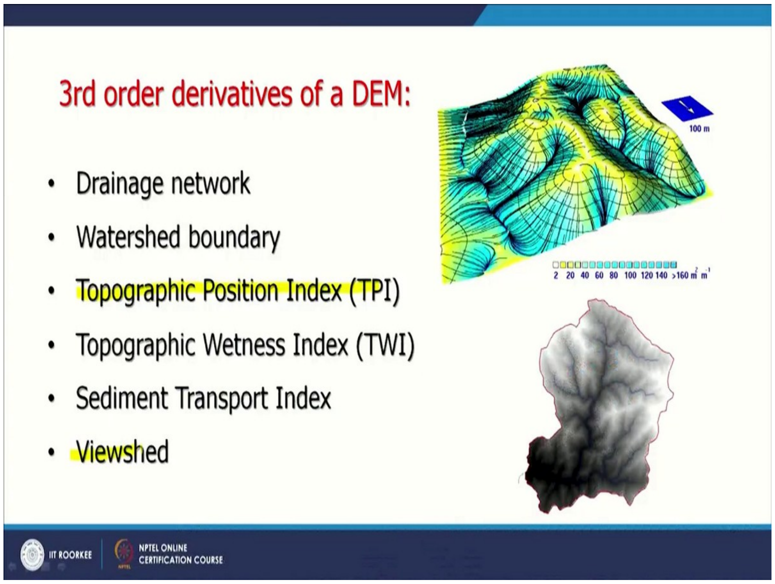

And then third order derivative; under this category comes the drainage Network and that we will be discussing in future. Also, the watershed boundary and this all will come through the surface hydraulic modelling. This part we have already discussed, the topographic position index. And also, topographic wetness index which will come through this surface hydrologic Modelling. And sediment transport index; this is also a product which can be created through the surface hydrology modelling.

Viewshed is a different kind of analysis for which surface hydrology modelling analysis does not required. It's a different thing, though we have already discussed this viewshed. So, these 2; we have already discussed. Other 4 will be discussed in surface hydrologic modelling.

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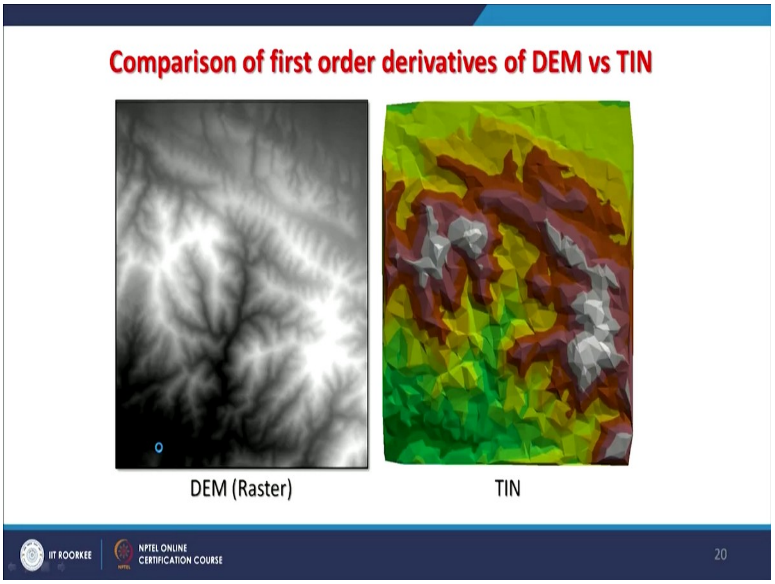

Now I am done some comparison of first order derivative using TIN and DEM. And what are the variations which we will be see, this is very interesting. So, what I find that when I derive first order derivatives then the boundary issues will come always with the TIN.

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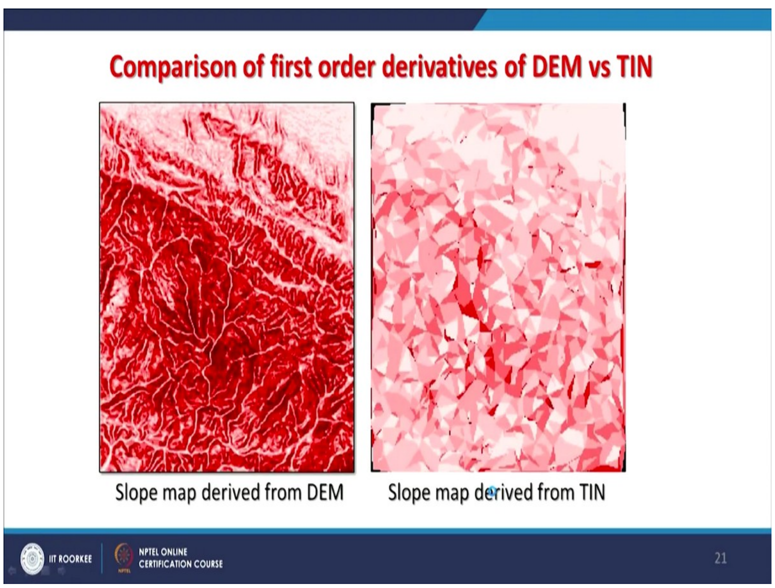

So that one thing very important. Now, this is first order derivative about the slope. So, for the same terrain, two different outputs because here I am having a raster in form of digital elevation model and here on the right side, I am having TIN. So, because TIN is represented through Triangles facets and therefore in your slope map, it is looking like this. Now in nature, things may not be exactly like TIN or DEM based slopes.

But because these are all models so it is not necessary that everything will match in the ground. But what should match is the inclination or slope values, that should match against the certain point locations in the field. Whether it's a TIN or raster-based slope map; these should match. But when we see in larger perspective means for whole area then the representation of slope maps through two different data sets, through two different data representation models can be completely different.

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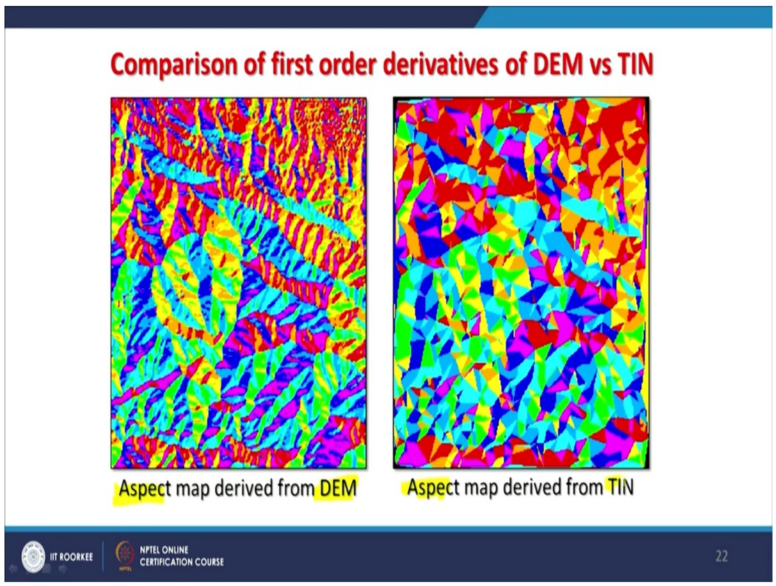

Now boundary issue will remain always with the TIN. Now same with the aspect. Like slope, the derivatives are different but overall representation is almost same in raster except that units are in TIN are triangle. So therefore, you know that influence is always there. Means triangle can be made smaller if we are having large density or huge density of our observation points which will be used to create a TIN. Then you may create a TIN of smaller Triangles and also one more condition is whether the undulations are there or not, that means these point inputs are having variation in z value or not.

I may have a high density of points for creating a TIN but if points are not having high variations in the z value, then again larger triangles would be formed. So nonetheless, we can definitely see the differences in the outputs of raster-based aspect and TIN-based aspect.

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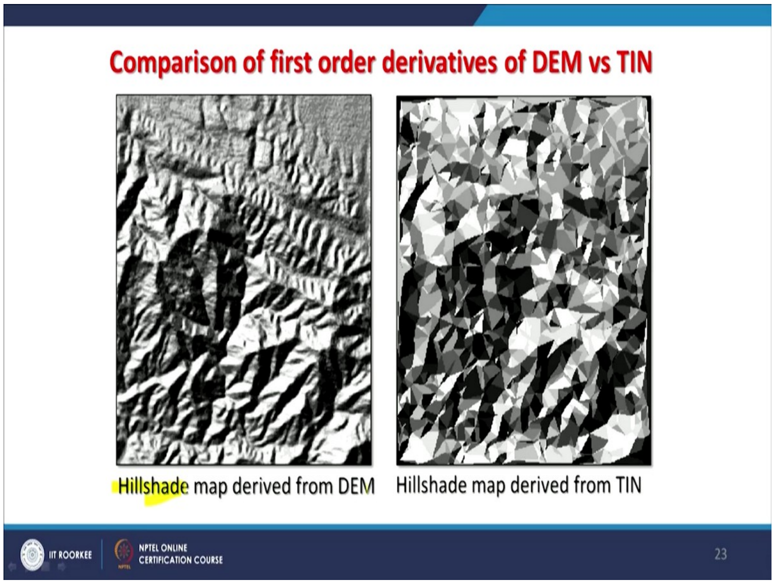

Boundary issue will always be there. Similarly, a shaded relief model or hill shade which you are seeing. These are the few derivatives which can be derived from TIN so I am comparing with the DEM also. But DEM also can derive or can create many other products which TIN cannot do it. Anyways but the best part is that for certain derivatives which you are happy with TIN, you can still use and whenever you feel that now you want to have raster, you can also convert into raster; that is also possible.

Because remember the input is the point data so using those point data against surface can be created through interpolation techniques.

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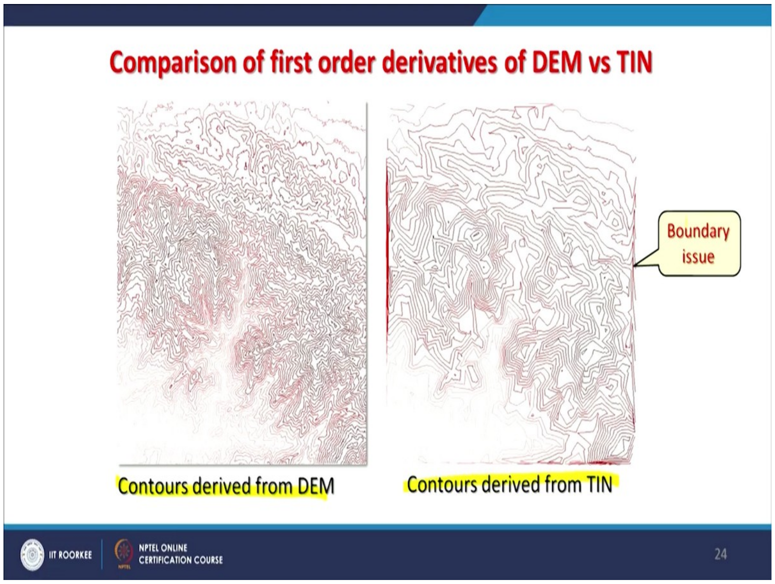

Now if I do it with the same contour interval, if I do it for contours drive from the digital elevation model and contours drive from the TIN. Again, the representation is going to be the different but overall, it is almost same because values are not going to change. Of course, the boundaries issue will always be there. In case of raster, the overall shape as you know can be either square or rectangular. But in case of TIN, it is arbitrary. It is not necessary always square or rectangular; rarely would be a square or rectangle.

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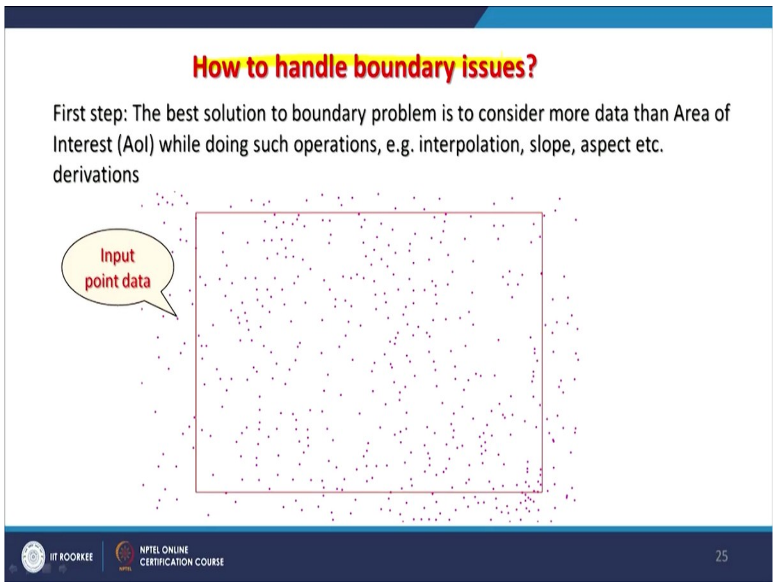

Now sometimes when we do; this is a little different topic related with of course digital elevation model. And when we are going for interpolation, creating a surface because it is not necessary that all the time whenever we are doing interpolations, we are only doing for a typical elevation model. We may be using point data for creating a surface for groundwater, for PH value or EH value or some other element or anything or pollution or other things.

So, whenever this situation comes and my area of interest say in this example is shown as a bracket or a rectangular. What I need to do? Always to take points which are going even beyond my area of interest. The advantage would be that if I take only points which are falling within my area of interest then in the border areas, the interpolation techniques will do extrapolation and extrapolation can produce lot of errors.

But in this case like I am having extent of my point distribution is larger than my area of interest. So, what would happen if I use these points data for creating a surface using interpolation technique? Though there would be extrapolation in the area or outside but at least inside of my area of interest, there will not be any extrapolation. And once a larger digital elevation model or a simple surface has been created using these extended points, what I need to do? I will just use the same polygon or this rectangle and create a subset of the digital elevation model.

So, that digital elevation model will not have any cell value which has been created through extrapolation. All the cell values would be through interpolation and this becomes very-2 useful because the error part would be very less. But if I take only for my extend like for this rectangle then at many places like here, there will be completely extrapolation. So, these areas will have errors because I do not have any observation beyond this boundary. So, it is always better. If that is possible, choice is there, do it.

So, the first step; how to handle boundary issues? The boundary issue problem to consider more data than area of interest or more points. While doing such operations interpolation, slope, aspect etcetera derivatives. So, boundary issues will not come in this.

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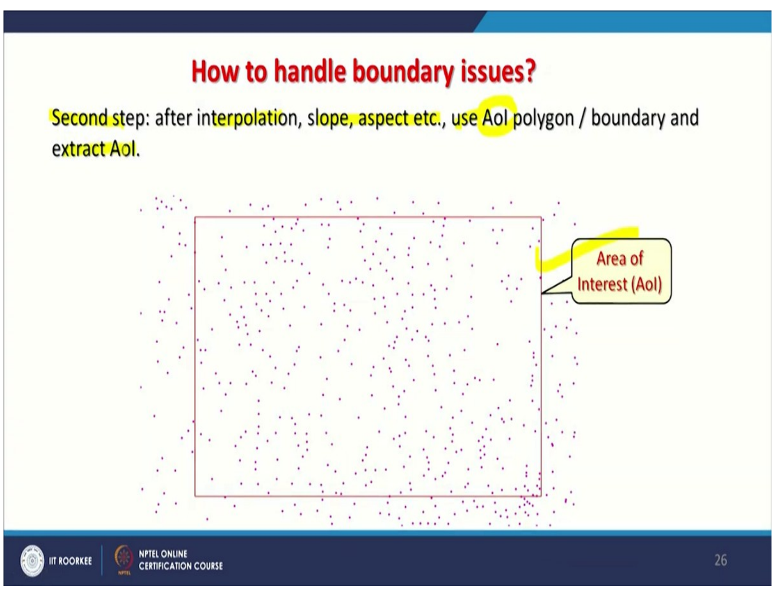

Now similarly the second step here as I am also mentioned that after interpolation slope, aspect etcetera use AOI polygon like this one shown as a red rectangle boundary and extract to or clip to and through which you can always create. Like here how to handle boundary issues which we have done it. One important point which I want to bring here is that recall the discussion related with no data.

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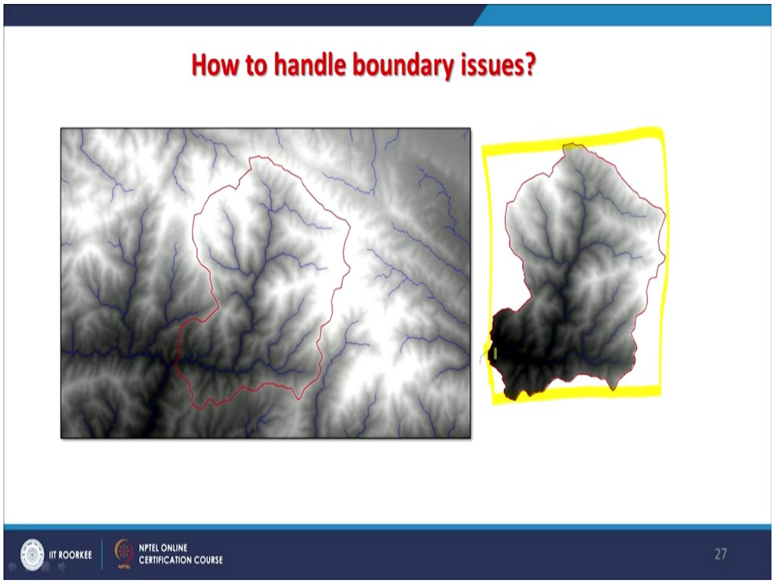

So, this watershed must be having a rectangular area like this but here in the outside of my watershed, it is being represented through Nodata. Nodata has been assigned by default or you can assign a background value of my screen. Generally, it is white then I will not see any Nodata. I would see digital elevation model or my drainage network only for my area of interest so this is how these things work very well.

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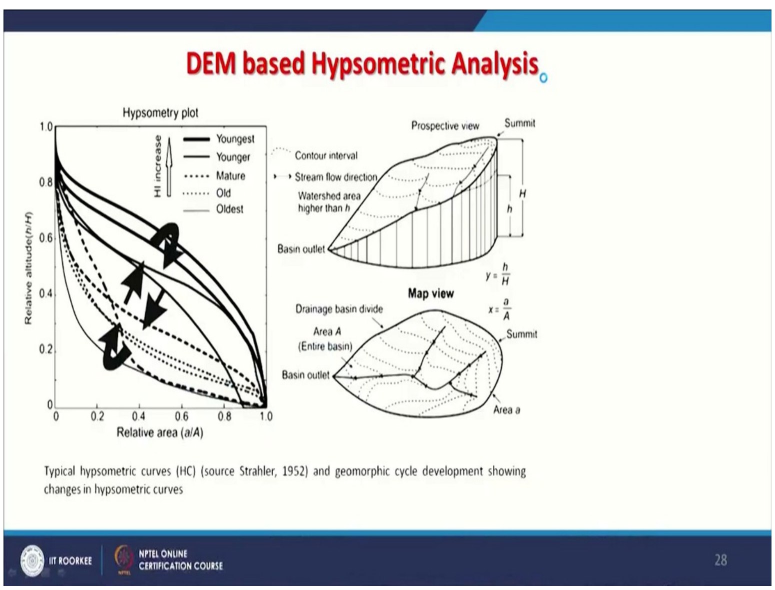

Now a little bit more about the hypsometric analysis which is again a DEM derivative and lot of research is being done using these things to understand the terrain, topography and fluvial processes as well. So, what we basically try hypsometric plots. Hypsometric plot we derive and like in this schematic, if I see that my curves are coming like this then I say that it is a very young topography. But if my plots are coming like this in the bottom like then I would say the oldest.

So how old that surfaces? That can be assessed through hypsometric analysis. Now, these are very-2 useful where lots of tectonic activities or erosional activities are taking place. Because of these activities, our valleys or surface or slopes cannot become older. They keep changing and therefore if we do the hypsometric analysis which is basically relative area versus relative altitude, we may get curves like this.

This thick black line curves so these will represent very younger terrain. So, any terrain using the age factor or we can indirectly use from tectonic point of view or erosional point of view. So, hypsometric curve is a histogram basically or cumulative distribution function of elevations in a geographic area. So, this is basically relative area versus relative height. And the hypsometric curve is one which is plotted to indicate the property proportions of the area earth surface at various elevations or depth above or below the certain data. So here we will be discussing only above the datum.

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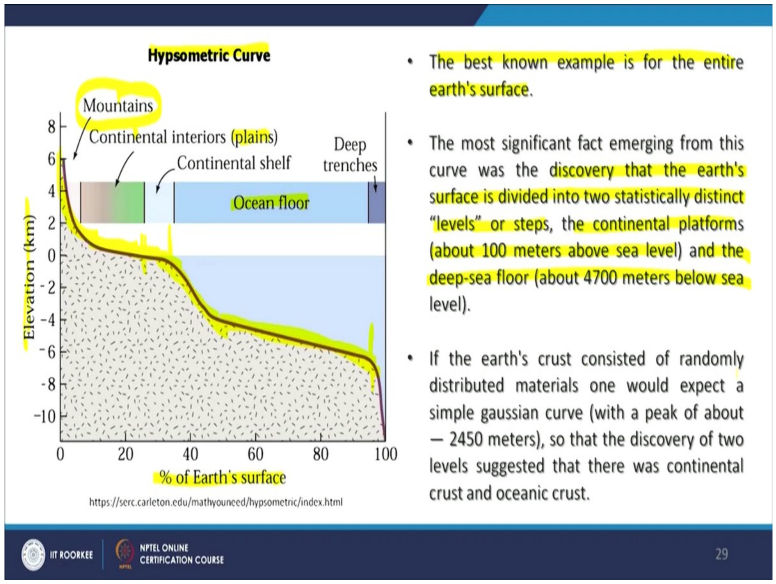

For example, this is a schematic. In this one, what we see that in mountainous terrain like Himalaya, we generally would see a hypsometric curve like this but when it goes in the plain areas in continental part, it may see like this then in ocean shelf area, something like this and then deep ocean floor area we would see like this. So, in continental shelf, this is the scenario and in ocean area, this is the scenario.

And if it is a trench area like very famous Mariana Trench, you may find the profile like this. So, how it has been plotted that the percent of the Earth surface versus the elevation. So obviously, like we know we say that Himalaya is a young mountain chain therefore in this kind of plot, we will come here and these curves will be like this. So, the best-known examples for entire earth surface which is shown here that the most significant fact emerging from the curve was discovery that the Earth's surface is divided into two statistical distinct levels or steps.

The continental platform; that is the land part about 100 meters above sea level and the deep-sea floor; that is 4700 meters below sea level. So, we know that exactly mountains and Continental Plains are one and then rests are in different. And if earth crust consists of randomly distributed material, one would expect simple Gaussian curve with a peak of about 2450 meters so that the discovery of two levels suggested that there was Continental Crust and Oceanic Crust.

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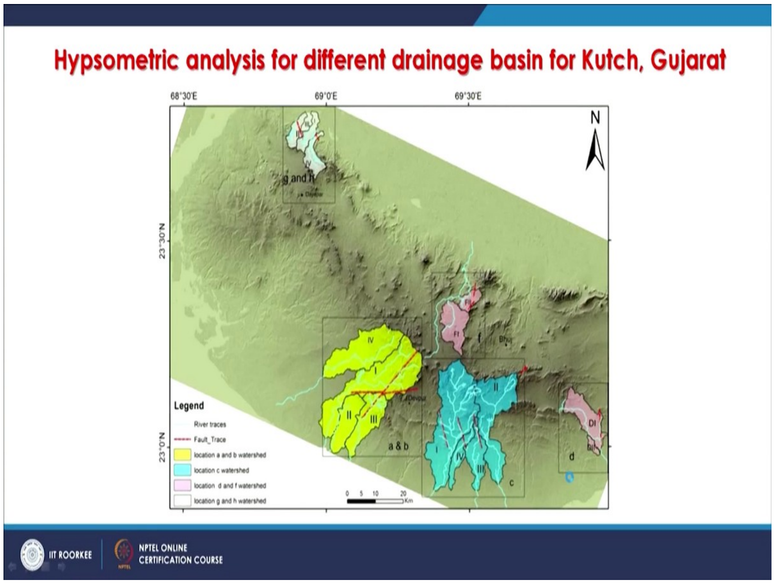

So, lot of interpretations. If we go for a global scale, can be done and also if we do this analysis for a local scale like here in this example has been done, for Kutch region of Gujarat which is tectonic very active region. Hypsometric analysis for different drainage basins. It is always good to perform such analysis based on hydrological boundaries because this is how the water flows and erosion and other things will take place.

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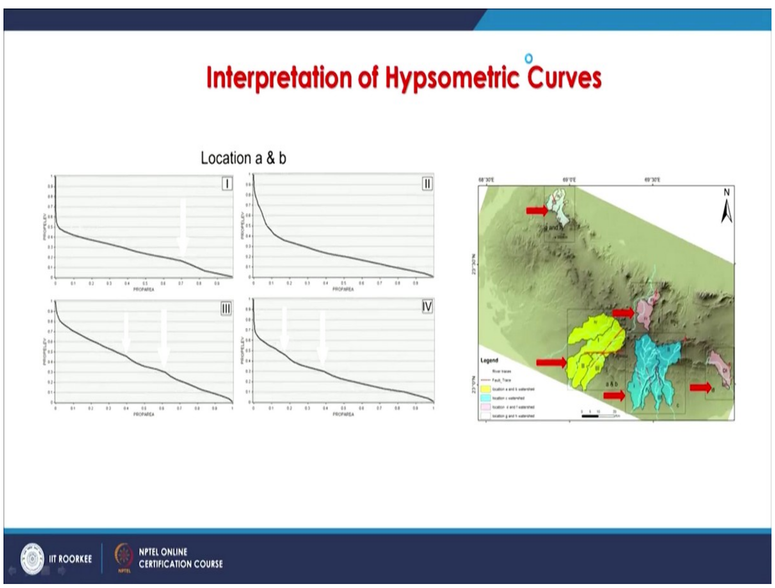

And these are the various watersheds which have been considered in this analysis. So, we find that because in this region, though there are tectonic activities but still these hypsometric curves are not taking this kind of shape as will happen in case of Himalaya but they are little taking near older kind of topography. One more example, here you are seeing and one more example for different watershed which you are seeing here likewise.

So, one single digital elevation model and tens of derivative; more than 20 derivatives so far, we have discussed and few more will be coming. So that is why I have been saying repeatedly before I end this discussion that digital elevation models and satellite images are store house of information. It is your capability. How much you can exploit these surfaces of these raster datasets. With this, I end. Thank you very much.