Geographic Information Systems
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Lecture-39
Digital Elevation Models and Different Types of Resolutions

Hello everyone! and welcome to this very important discussion about digital elevation models and different types of resolutions. As you know that digital elevation models are a store house of information and theoretically n number of derivatives can be generated using digital elevation models. So far about 20-30 derivatives are already in application part and many of them you would be discussing.

But before that, I thought let us discuss further intricacies about digital elevation models. Because like satellite images, DEM's are also very important input in any GIS operations nowadays. Because everywhere if people are working on terrain, then they have to imply the digital elevation model. So, this part I discussed little bit in the previous discussion about the spatial resolution.

But here we are going to have deeper discussing on spatial resolution. And we will see through examples that how we can differentiate which is better? and which is not so good? But overall, what I have said earlier and also, I have been saying that each resolution data is important, whether it is a 1-kilometer resolution data or 30-kilometer resolution data or 30-centimeter resolution data.

Because the application area of different spatial resolution data is going to be completely different so they are complementary to each other. But nonetheless, we must understand what is basically a spatial resolution when we talk?

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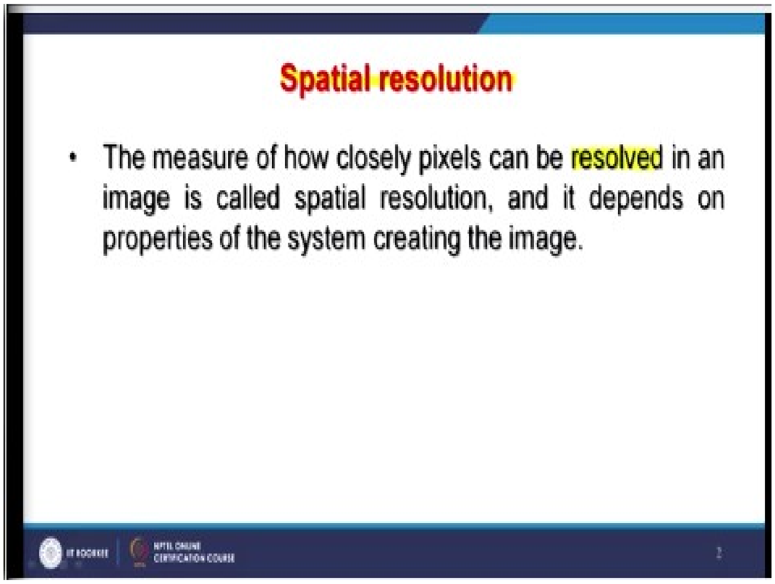

So, in case of satellite images we say that it is measure of how closely pixels can be resolved? So, if we can resolve those pixels in an image and that becomes the resolution of an image. And of course, it will depend on the properties of the system which is creating the image. Basically, it is the precision of that sensor which is generating. But why we are discussing satellite images? Because as you know that nowadays there are various techniques of generating digital elevation models which are based completely on satellite data, like stereo pairs, like SAR interferometry, or like Lidar, or like your thermal infrared data.

And therefore, there is a close relationship between remote sensing or concepts in remote sensing in digital image processing and also in GIS. Now as you know that in a simple term if I want to say about spatial resolution that means the clarity which I am having in the image or in my digital elevation model. So, this clarity basically decides by spatial resolution. Generally, what we have observed that high spatial resolution satellite images will be clearer than relatively coarse resolution satellite image and same with your digital elevation models. Now in remote sensing, as you know that resolution means the resolving power, how closely these can be resolved the pixels here?

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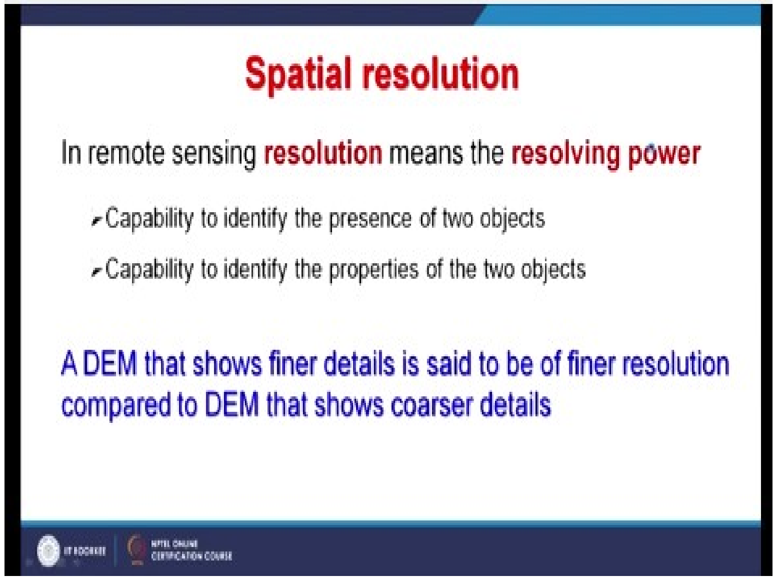

How closely the cells in case of DEM? which is again raster, a grid form and how and cells can be resolved? So, under this resolving power will allow or improves our capability to identify the presence of 2 adjacent objects very clearly. If a resolution is relatively poor then those 2 adjacent objects may not be distinguishable. Now the condition also here is that these 2 adjacent cells or pixels should have very distinct properties.

Then it becomes much easier to identify 2 adjacent objects but nonetheless this resolving power will allow us or will create the capability to identify the presence of 2 objects. Further this capability is basically as I have said depend on the properties of 2 objects. So, DEM which we are discussing shows that finer detail is set to be finer resolution. So, when we can identify small-small changes in elevation or in terrain through a DEM, we say is a quite good hi-fi or high fine resolution or higher resolution DEM compared to a coarser one.

But this is always in relative terms. Earlier as said in the previous discussion that NOAA-AVHRR, AVHRR stands for Advanced Very High Resolution Radiometer but it is no more now high. So, at that time it was high, so relatively that was high but relatively now when since we are having 60- or 40-centimeter satellite images and in that term that is not high. So, whenever we say coarse resolution, fine resolution, it is always in relative terms, relative to some resolution. Also, we briefly touched about 2 types of resolution which exist in Digital elevation model.

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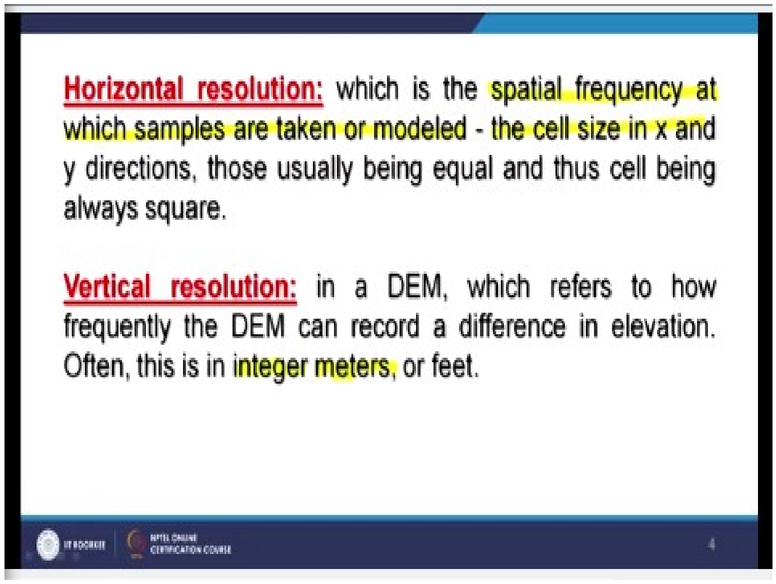

Whereas, in satellite images, there are 4 types of resolution exists. So, here we are not discussing satellite images resolution, we are discussing about the resolutions which are associated with a digital elevation model. So, first is when we say spatial resolution generally what we mean? is the horizontal resolution and which is the spatial frequency at which the samples are taken or modeled.

And basically, in that sense it is the size, cell size in x and y direction and as you know that this in raster format the cell is always a square. So, x and y are going to be the same dimensions, whether it is a 10-meter, 20-meter or 100-meter. And this is being equal and thus cell always be a square. However, remember also that overall shape of a raster or a grid or DEM can be either a square or rectangular.

The second type of associated resolution with the DEM is called vertical resolution; basically, it is the least count. So, this DEM in which we refer how frequently the DEM can record a difference in elevation? often this is an integer meters or feet. So, generally we talk nowadays most of the digital elevation models, which are available free of cost, the cell values are in meters and in integer values.

That means they are in whole numbers; you do not have decimal or fractions or floating point. So, that means the least count there is maximum 1-meter and that is why the vertical resolution there is 1-meter. And I also mentioned that it is need not to be the horizontal resolution and vertical resolution same. Generally horizontal resolution is relatively less as compared to vertical resolution.

Like, if I give example of SRTM 30-meter resolution so horizontal 1 cell is representing 30 meter by 30-meter ground area but vertically each cell can have at least 1-meter of variation, 2 adjacent cells and this is the least count in that sense. So, vertical resolution is often higher because the value is low here (more fine) than horizontal resolution.

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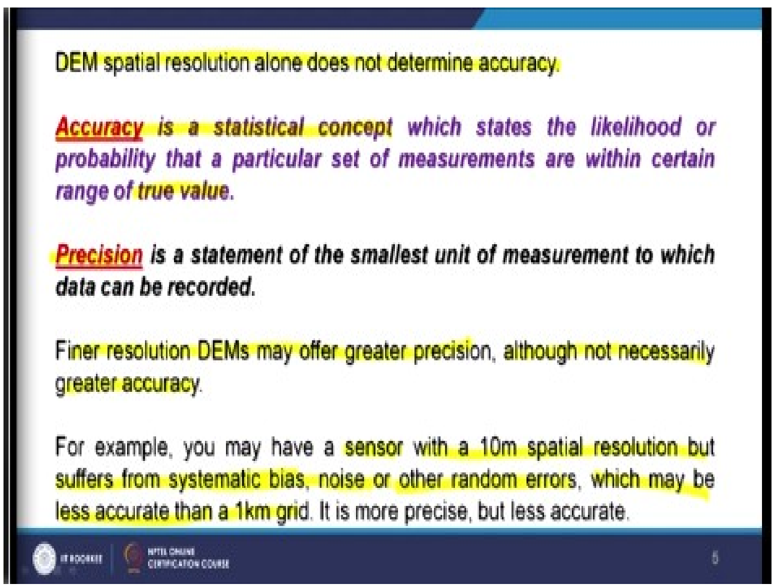

Now DEM spatial resolution alone does not determine the accuracy. This is a very important part and many people get confused, sometimes they use these 2 terms accuracy and precision synonymously but they are completely different terms. So, accuracy basically is a statistical concept or a statistical term which states that likelihood or probability that a particular set of measurements are within certain range of true value.

So, you are having some true value or a standard value when you compare your measurements and how close your measurements are. If they are very close, we say highly accurately measured. But if there is a very large difference between the standard value or true value and your measurement, then we say it is having poor accuracy. However, the precision is a statement of the smallest unit of measurement to which data can be recorded.

That means precision depends on the instruments which I am going to use. Suppose, I am having a 1-foot a scale, on one side I am having inches, another side I am having centimeter. Now relatively this inch’s side is having poor precision or less precision as compared to my centimeter side because as you know that in 1 inch, I can have 2.5 centimeter or 25 millimeters.

Whereas, if I make divisions in the inch side maximum, I can have 10 divisions and here I am having 25 divisions and therefore the precision of centimeter scale is relatively higher than in inches’ scale. So, same with the satellite, if a satellite is acquiring data at 30-meter spatial resolution, another one is acquiring 3-meter resolution definitely the precision or spatial resolution they are much higher in case of 3-meter.

So, whatever is higher spatial resolution. So, what the point was? That DEM higher is alone does not decide the accuracy, it is not always true that high spatial resolution will have always accuracy because as I have already explained, accuracy is a statistical concept. So, I may be having a 5-meter spatial resolution DEM but the elevation values which it is giving may have a large difference between my standard true value then compared to what this digital elevation model is giving.

So, always it is not true that high spatial resolution digital elevation model will also have a better vertical accuracy, so this one has to remember. So, final resolution DEMs may offer great precision, but not necessarily they will have a greater accuracy. So, because these 2 different terms altogether, one depends on how closely or how nicely we do the measurements? And thus, precision is based on an instrument or tool which be used to measure certain thing.

This measurement maybe the length measurement, this measurement maybe reflectance measurement or any other measurement. Now, further if we see that for a satellite-based sensor with a 10-meter spatial resolution, may suffer from systematic bias, noise or other random errors and which may be less accurate than a 1-kilometer grid. So, because you know that satellites are moving objects and some satellites were not moving in a design orbit, it may have all these errors, systematic bias, noise or other random. And if I use that data to generate a digital elevation model, I may not have that kind of accuracy as compared to a more data which has been acquired by a very stable platform though spatial resolutions might be relatively coarser.

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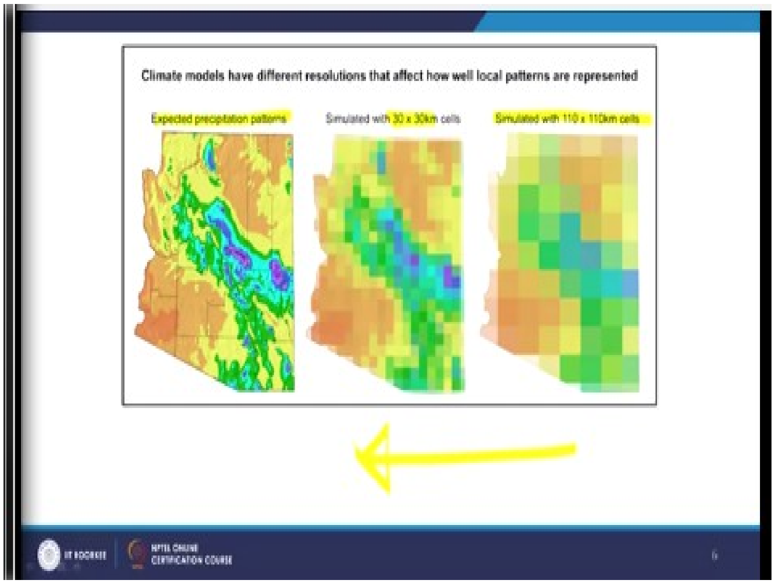

Examples, how do you feel about high spatial resolution or low spatial resolution? Here these are of course the simulated images but the real one I will also show. So, here the one cell is representing 110*110 kilometer area and as you can see that it is a completely blocky jugaard kind of appearance. And it is very difficult to resolve 2 pixels easily or 2 cells here easily. If I go towards the better side of spatial resolution, like 30 kilometers by 30 kilometers, then I start seeing some pattern but still it is not that easy.

But however, if I go for 1-kilometer resolution DEM, like this one or a satellite image, I start getting the pattern very easily. So, when we move from coarser resolution to higher spatial resolution definitely it is more comfortable for our eyes to resolve these 2 cells which are adjacent to each other. And therefore, they are more comfortable to read and make some interpretation out of that.

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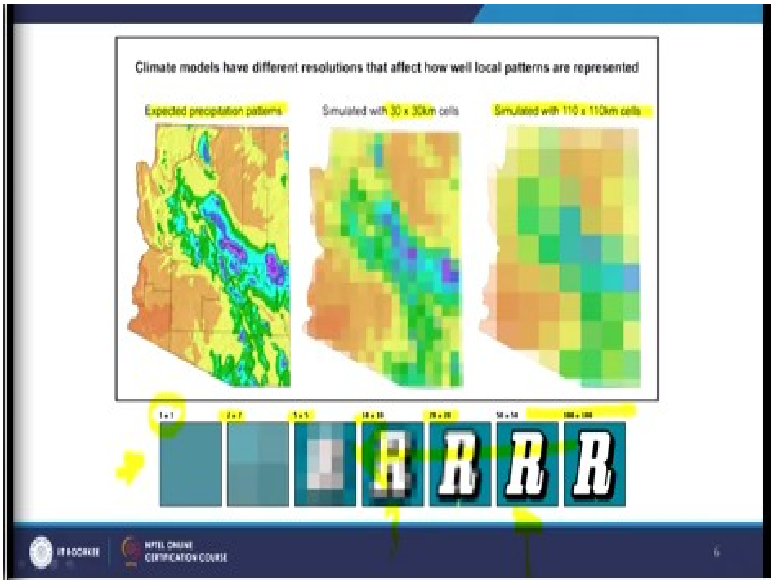

Another example is given here, the matrix is 1 by 1 and, of course, that is the unit cell and cell is a unit, it is indivisible, we do not see any variation within that cell but when we go 2 by 2 then we are seeing at least 4 different sets of that blue colour which you are seeing. And we keep moving like this, as soon as we come to this location 10 by 10 or 20 by 20, the letter R start appearing.

So, at this stage is still there is a doubt whether that is A or R. But once we improve the resolution, instead of 1 by 1 or 2 by 2 or 10 by 10, we go for 20 by 20 so number of cells are increasing and this is what exactly happens in case of your cameras. Digital cameras like in mobile when you move from 5 megapixels to 10 and 10 to above and now there are cameras which are providing resolution of 44 megapixels.

So, very fine details you can have through those cameras or capture those fine details. So, as soon as we enter here in the 20 by 20 then this letter R start appearing clearly. And, of course, then you keep moving but recognition of that letter will not improve except that it might look sharper and sharper. So, that means for this particular scenario, the 50 by 50 is more appropriate or optimized resolution to recognize such objects. So, that is why I said that always it is not good to go after higher and higher spatial resolution.

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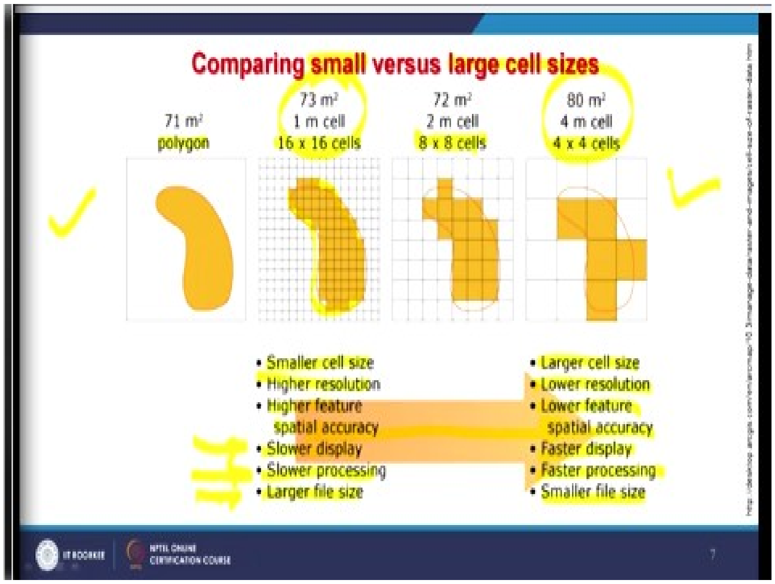

Another example here is that we are comparing small versus large cell sizes and what we see here is a polygon but when this polygon is converted to raster and that too 16 by 16 cells matrix, this is how the boundaries will appear. They are completely jagaard and stair steps case kind of thing but when we bring at 8 by 8 cell they are further deteriorated. And when we are bringing at 4 by 4 cells just you are seeing. Now here comparing this rightmost one and the leftmost one, see the input polygon had show a smooth boundary and this 4 by 4 cell one is having by very poor representation of that polygon.

So, when you move from higher to lower, this is what happens? that smaller cell size here for a 73-meter resolution, 16 by 16 grid in this example. Here the cell size has increased i.e., 80 square meter then higher resolution, of course, this one relatively is lower resolution, higher feature spatial accuracy, lower feature spatial accuracy. Of course, because number of cells are more therefore it will take more time to display as compared to the less number of cells in the rightmost examples. So, lower processing, faster processing, large file size, smaller file size.

That means, if I take this one and this one in example then both are having some advantages or disadvantages. So, it depends what are our requirements or target for projects and scale which is we have to produce the result in GIS. So, if we can decide that which resolution data have to imply because now choices are increasing even for different spatial resolution DEMs, for 30 meter 3 choices are there.

But less than 30 meter few choices are there, at 1-kilometer again you are having few choices at 90 meter not many choices. So, depending on our project requirement, targets, we should choose very appropriately the spatial resolution. I am repeating again it is not always good to go always for higher and higher spatial resolution because if you go for higher spatial resolution then you are going for slower processing larger files and slower display as well. You may or may not achieve high accuracy because that part we have already discussed.

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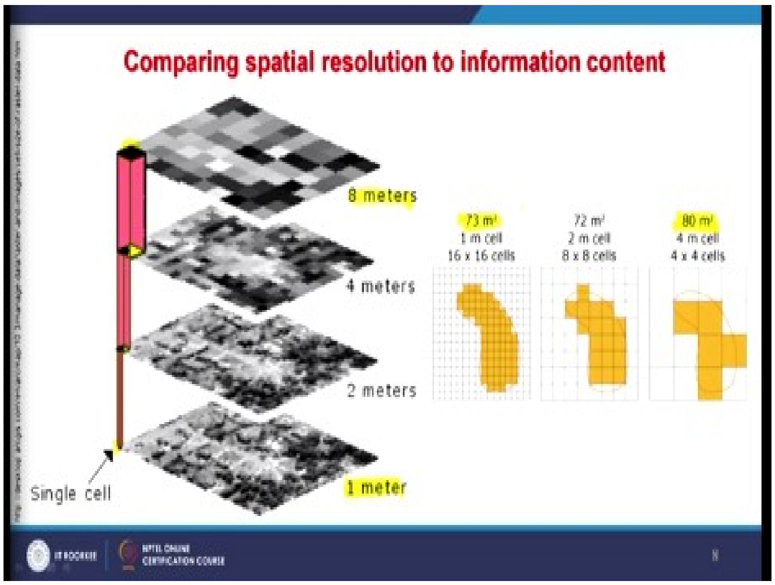

Similar thing here that when cell is very small then you are having a higher spatial resolution relatively and when cell size is large like here, it is 8 meters then you are having a coarser spatial resolution. So, it depends the area of the cell which is representing the ground, if it is represent a single cell is representing the large ground area. Like here, then it is having coarser resolution as compared to this one, which is representing a small area.

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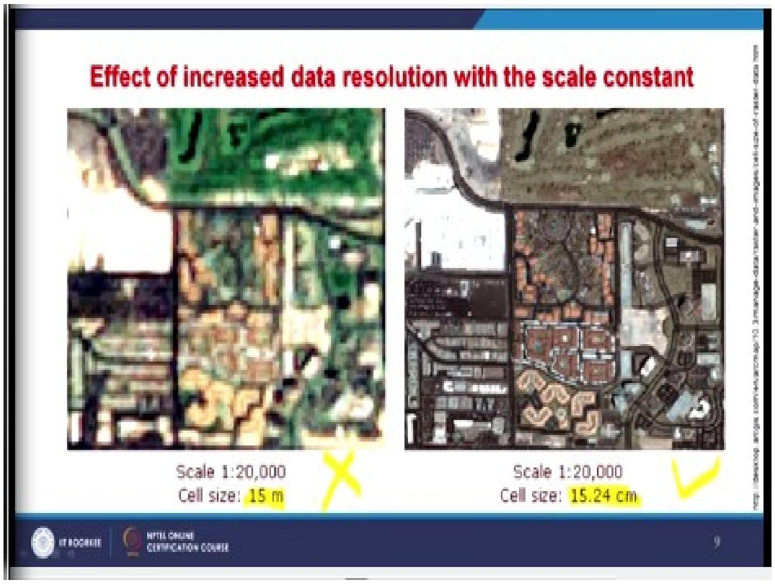

In case of satellite images visually you can see very well that these 2 images are covering the same area but one is having pixel size or spatial resolution is 15-meter and here it is 15.4 -centimeter, there is a change in the units so be careful. This is 150-centimeters and this is 15.24 centimeter means there is a huge difference (ten times) between spatial resolutions. And obviously which is big and therefore these cells or pixels are getting dissolved and you are getting very good quality picture or satellite image here as compared to this one.

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So, for many-many cases, higher spatial resolution may be very beneficial. There are other requirements in your project like, this scale has to be if I am working on a 1 raise to 2500 scale, then definitely I need a higher spatial resolution in satellite image. But here a spatial resolution in this example is the same, scale has changed for the same area and, of course, the effects are there.

So, effect of increasing the scale with the constant spatial resolution, there will be definitely different results. Now the thing is, if I have to produce my results at 1 raise to 50,000 scale then why I should use this 60-centimeter spatial resolution, I may resort and may compromise on the spatial resolution because ultimately, I have to produce my results at 1 raise to 50,000 rather than at 1 raise to 250,000 that was the purpose of showing this one.

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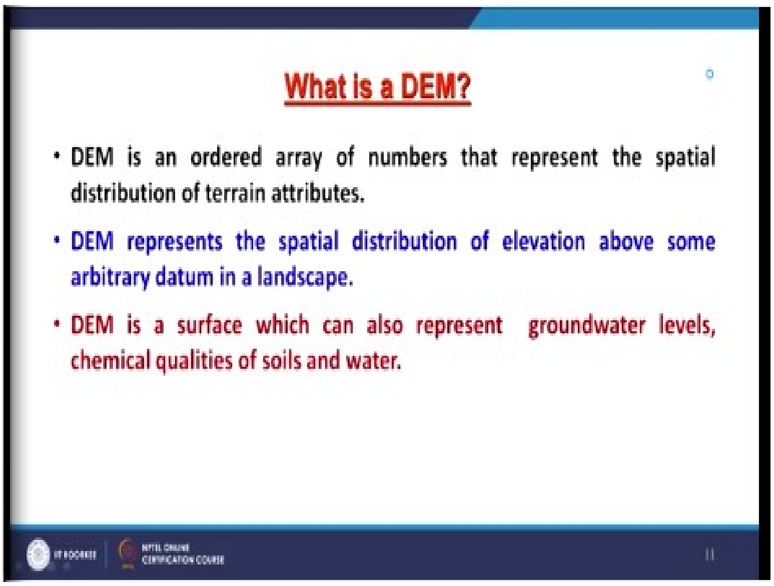

Now DEM we have already discussed, so just for completeness I would repeat that part, say ordered array of numbers that represents the spatial distribution of terrain attributes and when we say DEM the middle letter the E is for elevation. But this E value can be replaced with other properties also and basically as you also know that DEM represent the spatial distribution of elevation above some arbitrary datum in the landscape.

Generally, the digital elevation model, a typical digital elevation model which we use are representing elevation values above mean sea level. And these surfaces are continuous surfaces, can also represent if the property is not elevation, the cell value is not elevation. Then we can replace that value with groundwater levels, chemical qualities of soil or water and other things. This is again very typical example of a digital elevation model being displayed in grayscale.

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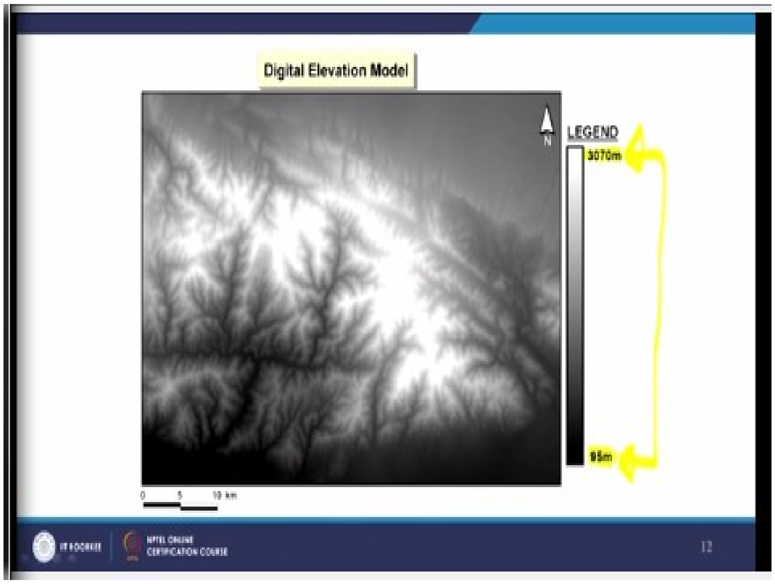

And the elevation ranges are between 95-meter to 30-70 meter lighter. Generally, this is how people prefer to display the higher values, higher elevation values are always given the lighter colour or lighter tone as compared to the darker one. So, this is the standard way of displaying digital elevation model. Just looking this digital elevation model one can have the feeling of the terrain and not only that but also by looking these elevation values minimum and maximum. That will give you a feeling that roughly in a 50*50 kilometer area one can have values varying between 95 to 30-70 meter.

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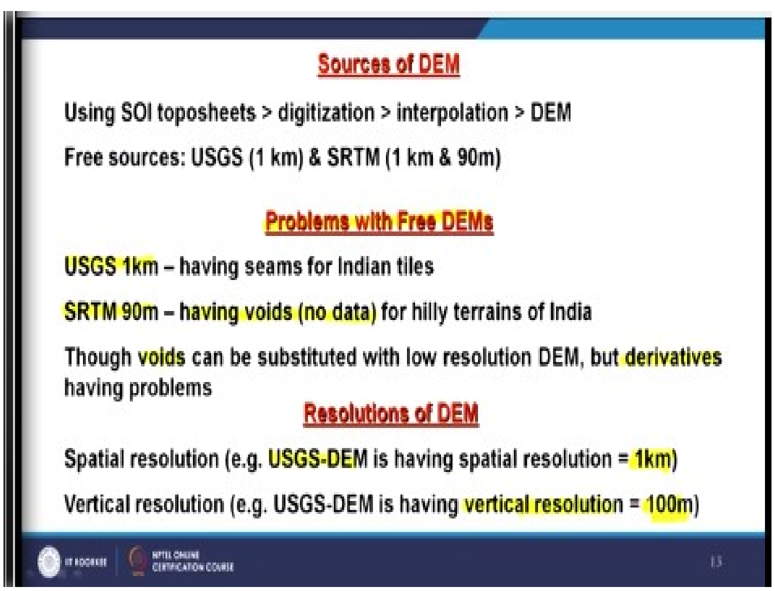

Sources of DEM which we have already discussed with this part, I am skipping here, lot of discussion will also take place in future about the different resolution DEM depending on what derivatives we are going to have. So, the only point which I want to bring here that when we substitute voids with low spatial resolution cell values from those DEMs then will be deriving already or creating some output from those digital elevation models which are void free may provide some problems.

So, therefore, it is very-very important that is why this discussion is again here is that because this SRTM 90-meter resolution while it is higher but it had the voids. Now the voids have been filled but these have been filled by 1-kilometer resolution and therefore when I use such a void field 90-meter SRTM-DEM and derive some parameters or derivatives then I may have some problems.

And resolution's part we have already discussed about different one, like for example USGS-DEM, it has the spatial resolution 1-kilometer and whereas the vertical resolution had 100-meter. But nowadays this SRTM-DEM or ASTER-GDEM or Cartosat DEM, they are having much-much higher resolution, vertically as well as spatially.

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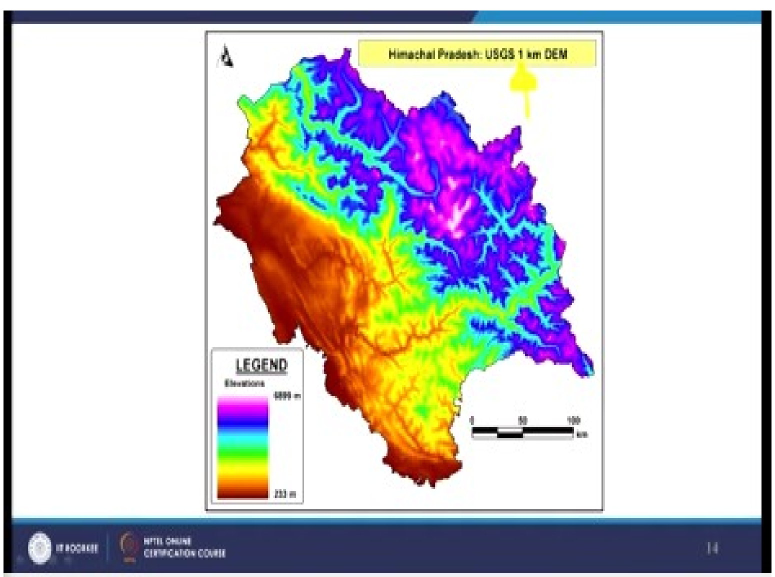

This example I am again bringing with a different discussion here.

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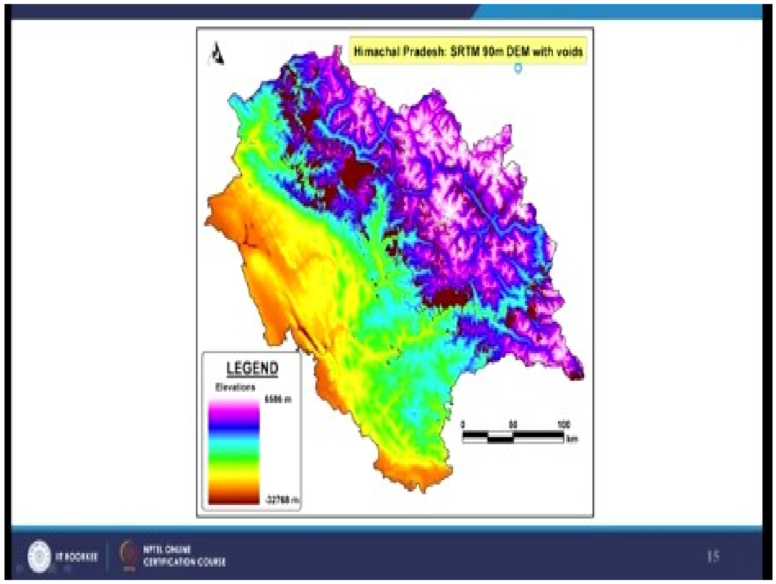

That this is the USGS-DEM of 1-kilometer, this is a 90 meter.

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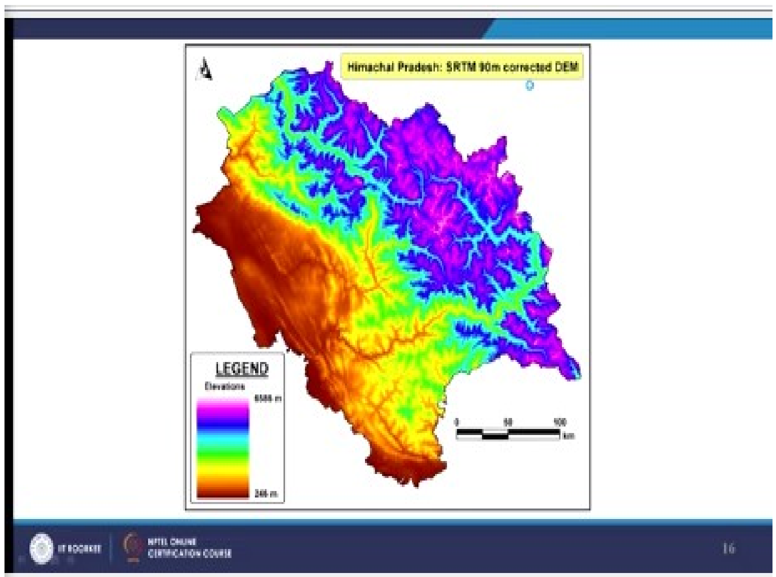

Again, this is void filled.

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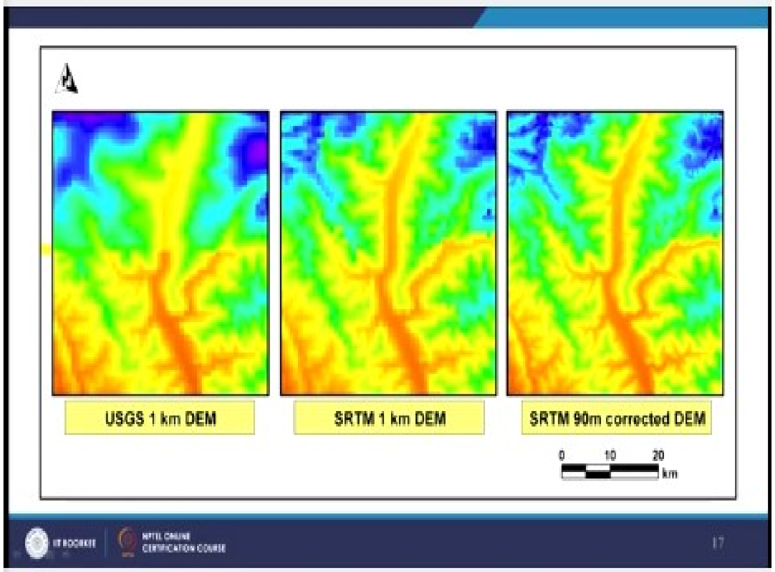

And you see the results, you can compare the seam is a little problem here.

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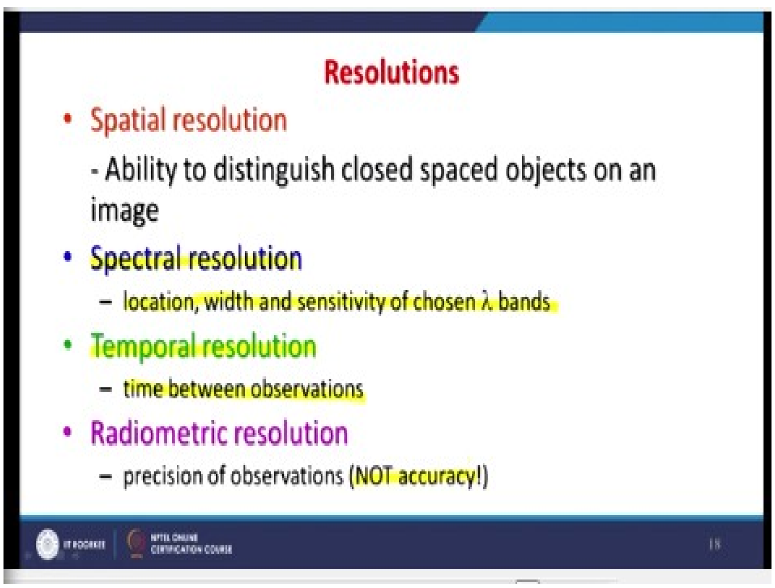

And this also we can wrap up by now saying that spatial resolution basically is the ability to distinguish close space objects on an image whereas in case of satellite images there are 4 resolutions. Spatial resolution is common both in satellite images and DEM whereas, in case of satellite images we will have a spectral resolution and because we are using satellite images to generate digital elevation model. So, it is also necessary to know about that.

So, this basically depends on where our bands are located? and what is their width? And the sensitivity of a chosen lambda band means where they are located in EM spectrum? Because at different locations the sensitivity is different. And generally, like thermal bands are having very broad width as compared to visible or infrared.

So, that will depend. And high spectral resolution means, for a same part or for a small part of electromagnetic spectrum, I may be having many bands as compared to having less number of bands. If I give example of Landsat MSS and TEM then relatively TEM had less spectral resolution as compared to TEM, ET or MSS. So, MSS had the less spectral resolution whereas TEM or ETM+ or OLI are having better spectral resolution.

Another term among the resolutions in remote sensing data which is called the temporal resolution. Basically, is the repeatability, how frequently that satellite visits the same area that is the time between observations. So, that is also very-very useful particularly in chain reduction studies or monitoring something. So, this will again depend on the spatial resolution, coarser the resolution, higher the temporal resolution.

That means, there is an inverse relation between spatial resolution and temporal resolution. Because coarse resolution means the swath is much wider, the path is also wider and it will cover a large area. So, therefore it can revisit the same area maybe twice in a day, in case of like NOAA-AVHRR data which is having 1-kilometer spatial resolution but a satellite IKONOS which is having 1-meter resolution will visit that area maybe after 30 days, 40 days and the swath width is only 11 kilometers because of that.

So, there is an inverse relation between spatial resolution and temporal resolution, higher the spatial resolution, poor the temporal resolution and vice versa is also true. And the last one among these resolutions in remote sensing is radiometric resolution. That is nothing but the precision of observations. And remember, this is not accuracy because these are 2 different terms precision and accuracy which we have already discussed, so no more confusion about.

So, how accurate, how precise your observations are depending on the instrument that is the sensitivity. So, if it recording at 8 bits and another sensor is recording at 12 bits, 11 bits, then radiometric resolution of 11 bit is higher compared to 8 bits. For example, our IRS-1C, 1D they were recording like pan data at 6 bits radiometric resolution and whereas in other sensors panchromatic data was being recorded at 8 bits. Like in the case of NOAA-AVHRR each the radiometric resolution is 11 bits, so it is relatively higher.

So, a sensor which may have a spatial comparatively poor spatial resolution but may have high radiometric resolution and also will have high temporal resolution. So, there is an always tradeoff between resolutions, you gain something you lose something and it depends on our requirements and projects accordingly one should choose these resolutions. Further, as we are discussing in context of remote sensing because 4 very well-established techniques of generating digital elevation models are remote sensing based.

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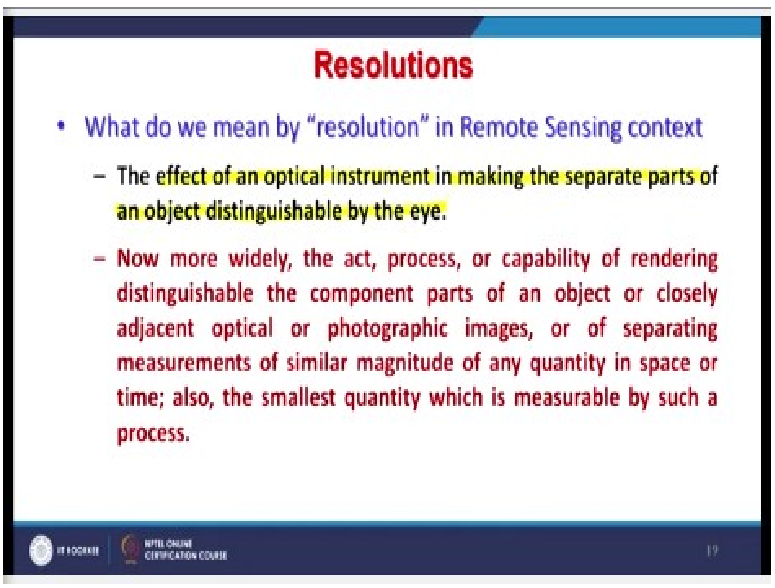

So, therefore, it is worth discussing that effect of an optical instrument which are generally used like stereo pairs data also use which making any separate part of an object distinguished by the eye. So, that will depend, of course, on your spatial resolution. And more widely, the act, process or capabilities of rendering distinguishable the component parts of an object are closely adjacent optical of photographic images.

So, basically in a nutshell, what we can say especially about the resolutions and particularly about the spatial resolution? more the clarity I get in my images, I get a better resolution. So, with this, I end this discussion, thank you very much!