Introduction to Geographic Information Systems
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Lecture - 13
Digital Elevation Models and different types of resolutions

Hello everyone, in this particular we are going to discuss basically different types of digital elevation models and their issues associated with them. And also we will see the different types of resolution which are considered in remote sensing in GIS; especially we will be focusing more on a spatial resolution. What basically spatial resolution means and when it varies how and appears in the data or of a digital elevation model may vary. As we know that a digital elevation model is a raster representation it is a surface and it is in grid form

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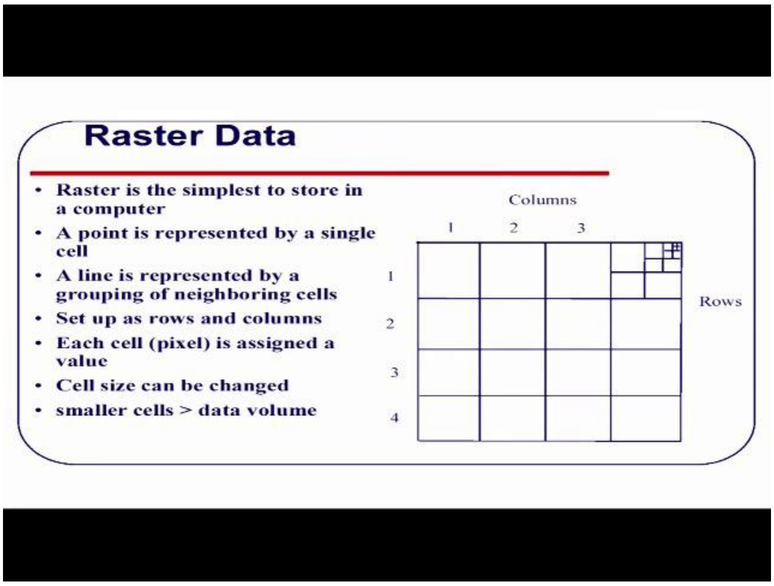

So, each cell represents a value and as you that in the raster each cell or pixel can have only one single attribute. Here, if we consider as elevation value then we call as a digital elevation model, but a sometimes people also use a term digital terrain model. And basically it is mathematical a surface which might be created through interpolations or might be digital elevation model might come remote sensing data analysis as well. Depending on the size of the cell resolution is decided and this is like here that in this particular example a cell has been further divided.

So, here you are having the smallest unit and it will have its own value, and therefore if you are having an entire grid having this much size of cell then is relatively is going to be the higher spatial resolution. But the same time the data volume is smaller the cells, the data volume would be very high relative to cell size remain like this, so this one is to keep in mind.

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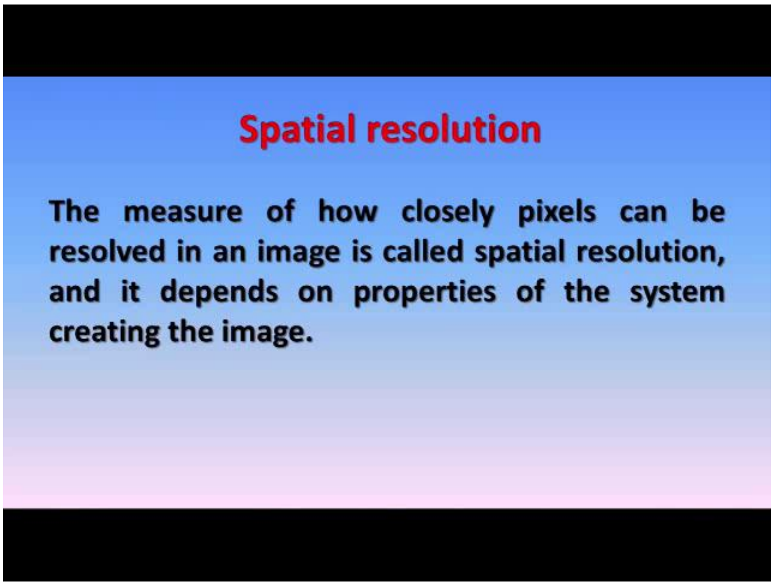

Now spatial resolution as we can understand that is major of how closely pixels or cell can be resolved in an image or grid is called a spatial resolution and it depends on the properties of the system creating the image or your grid. If you are creating a surface using point data through interpolation technique at that stage we can decide in mapping units at what resolution I want the surface.

But in case of satellite data during only design process it can be decided. Before I go further detail in this I would like to bring two three things about digital elevation model particularly, because now a days it is free digital elevation models of different resolution right from variety of methods are available free on net for entire globe.

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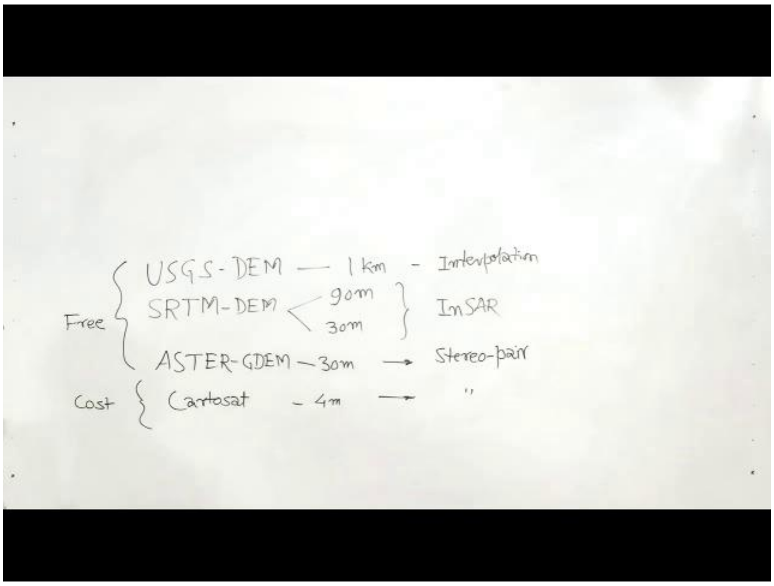

The earlier one the most popular one was their which is called United States Geological Serve DEM, and initially it was available at 1 kilometer resolution. Now this DEM was created using (Refer Time: 03:56) contour lines, those contour lines were interpolated and surface were created. So, we can write here say interpolation; the method here is interpolation, the source database (Refer Time: 04:13). Then a DEM which is again is quite popular which is called SRTM-DEM, SRTM stands for Satellite Radar Topographic Mission.

Basically, it was a 20 days mission of NASA which uses the sarferometric technique of remote sensing and covers the entire globe almost the 90 percent of the globe except the Polar Regions. And create DEM’s for the entire globe at two different resolutions one is has 90 meter and one at 30 meter. So here the method which we can write here is InSAR, SAR interferometry in short we say InSAR.

Now the third a type digital elevation models which are available now and for the entire globe is called ASTER-DEM or ASTER-GDEM, it is available at 30 meter resolution. When I say 30 meter resolution I mean spatial resolution 30 meter is a spatial resolution and the technique has been used is stereo-pair. This technique can also be implies with Indian remote sensing satellite like Cartosat and others and you can create a digital elevation model of 4 meter spatial resolution the technique remain same. These are freely available this you have to create, this is at cost. So, these models are available digital elevation model, there genesis are different and their spatial resolution are different. Now basically depend for what purpose you want to have a digital elevation model.

If you are going to cover a large area then relatively spatial resolution digital elevation model will be sufficient for you. But if you are working in small area then one should go for higher spatial resolution DEM, because area of coverage is going to be less. As we know that higher spatial resolution brings clarity in your image.

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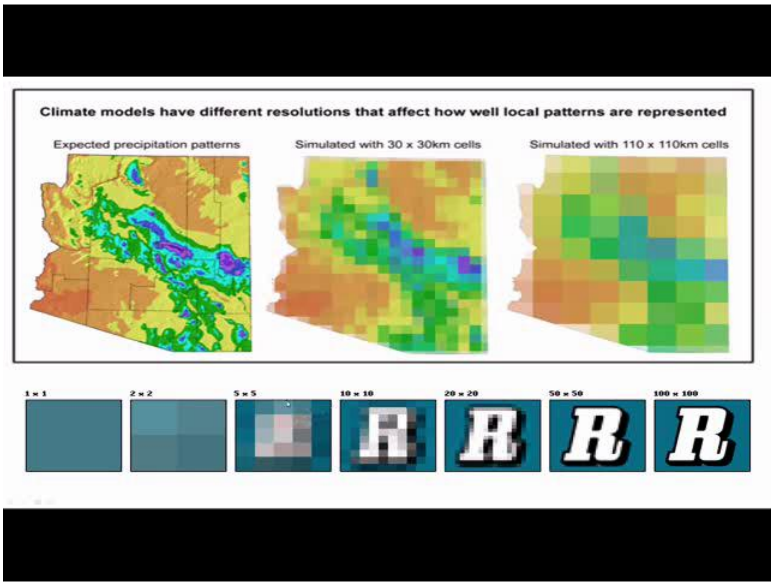

If we go for relatively coarser resolution two examples are given here that is 30 kilometer cells like this or 110 kilometer cells hardly anything can be seen, this depending for on what problems you are working. But sometimes like here the example is shown for climate models, because if for climate studies or climate changes that are you might be covering the entire globe and therefore going for say 30 meter or 1 kilometer resolution it would be too much data to handle. And you may not achieve whatever you want achieve through those climate change model. So, you may go for relative coarser resolution data.

And therefore one has to know the purpose and according different spatial resolution model one should be used. This example also is that when you having the grade 100 by 100 for same area then this character r are appearing much sharper. And when this number cell reduces for the same area here like 5 by 5 nothing is visible here and in between it improves as go for a smaller size cells. DEM is a discussed already that is a digital elevation model and each cell is a raster at a grid and each cell of a grid representing an elevation. Now the value can come from variety of techniques which we have discussed. Basically this is a surface it represent spatial distribution of elevation values above some arbitrary datum in a landscape.

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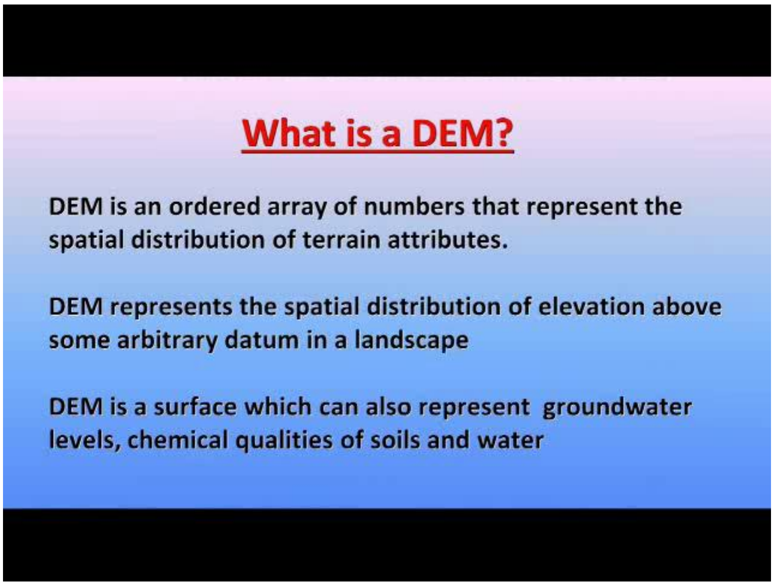

Generally we represent above (Refer Time: 08:55). And DEM is a surface which can represent may be groundwater, maybe chemical qualities of soil, water. Whatever the phenomena which varies the distances can be represented using the same concept. We may not called as a digital elevation model we may call it as simple surface.

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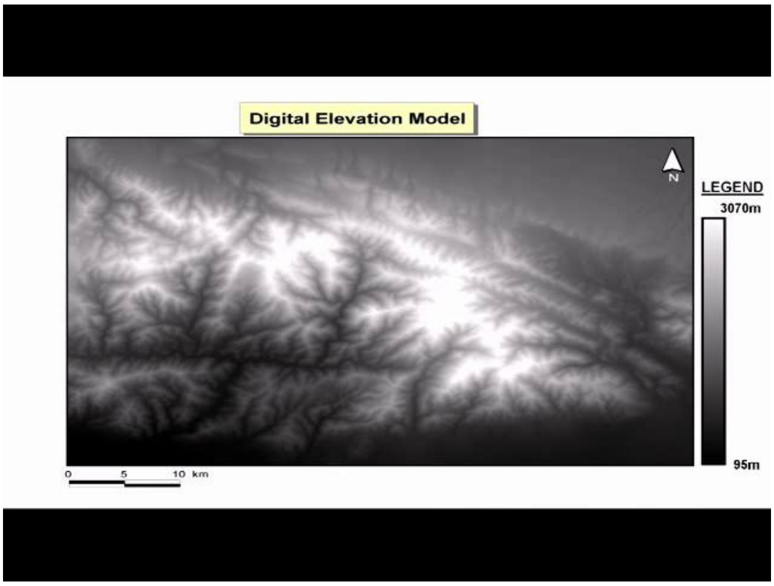

One of the examples for digital elevation model is given here, and this elevation model is having elevation ranges between 95 meter to 3070 meter and you can then assign some colors of shades of grey, like here for highest value white color for lowest value dark color and rest of the values are in between. When you are having this kind of variation of a terrain in a small area you can see even the values and extreme network which are visible quit easily here.

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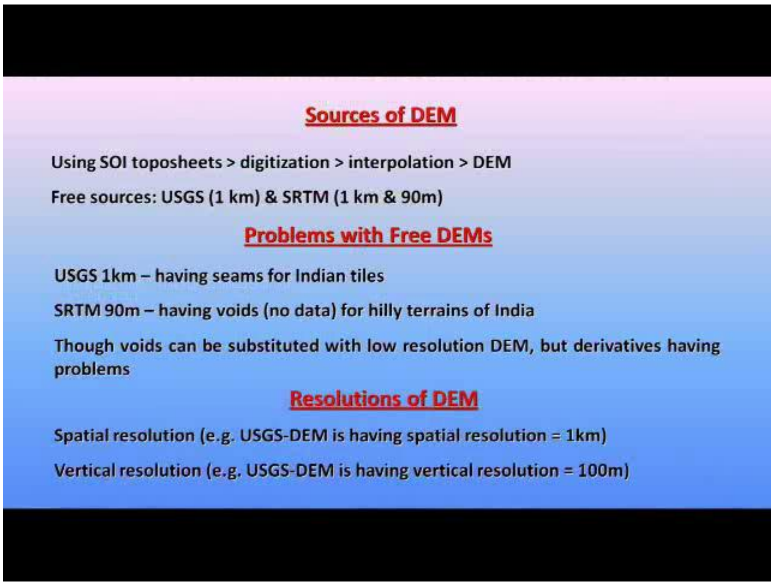

Now sources of DEM some of the freely available DEM's which I have already mentioned here, that you can digitalize data or you can by range digital toposheets take the contour lines convert them to point and using interpolation in GIS you can create the surface. Through interpolation you can create the DEM or download the free DEM of USGS-DEM, SRTM 1 kilometer and as well as 90 kilometer. And there are certain problems with free DEM's like USGS-DEM for Indian tiles it is having seams, because as mentioned here that this have been used by using the interpolation. So, the maps might be having a different projection or might be serve at different times, maybe having different density of a contours or intervals of contours and therefore when you joint two toposheets together you might get that seams.

So, this is the problem of USGS USGS-DEM of 1 kilometer resolution of Indian times. 90 meter resolution had lots of voids a for the hilly terrains of India is basically because of Himalaya terrain and as you know that for SRTM which is satellite radar topographic mission using InSAR technique two resolution DEM's where created a also 1 kilometer 90 meter data is around 30 meter now it is available. This is based on ASTER technique and as you know Himalaya is having large area is under snow and ice and therefore whenever you find this kind of problem in radar because of different dielectric constant. In radar remote sensing you do not get a desired data and therefore when DEM was created it developed voids.

Little later we will see how voids can be removed, but any way for hilly terrains of India and voids there even at 90 kilometer resolution 1 kilometer resolution and those other resolution as well. These voids can be substitute the values or these voids substituted with lower resolutions or some other. And like spatial resolution of this one having 1 kilometer say example USGS-DEM whereas for the vertical resolution USGS-DEM having the 100 meter that is the least count or accuracy or vertical accuracy of DEM. So, depending on the DEM different DEM's they are having spatial as well as vertical resolution.

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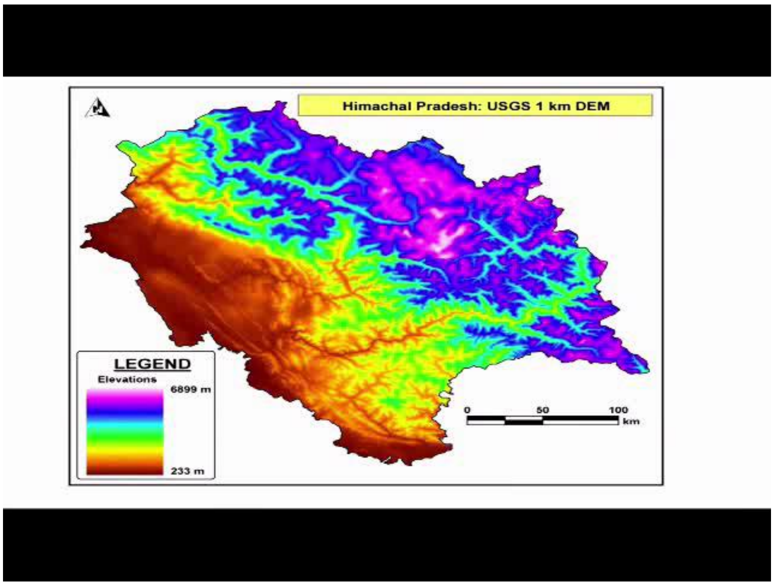

Now this is what void and tie the same problem with the USGS. This is the example Himachal Pradesh as you can see that there might be a one toposheet here and another toposheet might be here and therefore the seams is very obvious and it is clearly visible here. So, this might having high density or a close interval contours where might be having a large interval contours, and therefore you the seams are visible in 1 kilometer resolution of DEM Himachal Pradesh or many parts of India especially of any terrain.

Now the problem about voids, so in the 90 meter resolution the DEM it had the voids and voids gets the no data value in GIS as no data value while the signed here is minus 32768 that is then no data value not the 0 value. Now how get rid of these voids, because we get rid of voids then and this a digital elevation model will become very smooth and we can use for different analysis purposes.

One way which became popular is a filling these voids or replacing this no data values, using a coarser resolution digital elevation model like USGS-DEM. So, if you overly both of these create 3 voids as a blank areas and read the values blow from a coarser resolution DEM and then take that value as again this voids then you end up with a digital elevation model which is now void free at 90 meter resolution except places where the voids might be 1 kilometer resolution. So, if you not aware you will not be noticing correction here, but if you zoom this some certain parts you may find this is 1 kilometer resolution this is suffering from seam this is 1 kilometer resolution SRTM-DEM.

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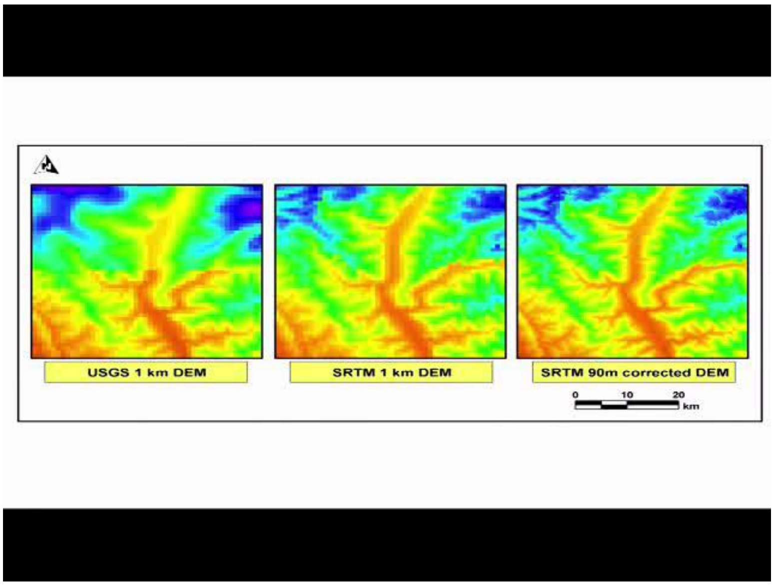

And this is now corrected void free and you can see that it look much better. And smoother of course, I say 90 meter resolution DEM.

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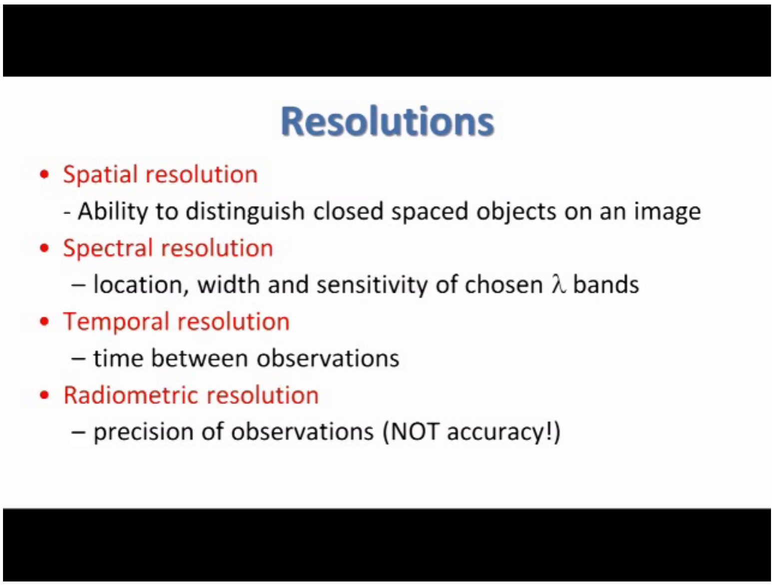

A resolution there is 4 type of resolution exists in remote sensing and these are also influencing in GIS domain. One is spatial resolution, spectra resolution, radio matric resolution and temporal resolution. So, these four resolution, but mainly we are focusing in GIS is spatial resolution which we have already discussed that ability to distinguish closed spaced object on an image. Spectral resolution is a location width and sensitivity of chosen lambda bands or a basically it is a bandwidth in a part of (Refer Time: 15:59) electromagnetic spectrum.

Now a days we are having hyperspectral bands; that means, bands are become very narrow and therefore we say it is a high spectrum resolution data. In earlier remote sensing technique like or sensors like (Refer Time: 16:21) we had relatively quiet broad band and we say coarser spectral resolution, so number of bands have been increased. In earlier sensors like (Refer Time: 16:32) we had only four bands, now there are sensors available on board satellite which can acquire data at 512 or even 1024 bands 256 band for almost same part of electromagnetic spectrum. So, the width of the each band is getting reduced even 1 micron size bands are nowadays available. But depends again for what purpose you want to use that data.

And the third type of resolution is temporal resolution that means, time between observations then because satellite are orbiting they are many satellite are not revisiting same time closer the resolution the revisit time will be much longer and sorry, the coarser resolution the revisit time will be shorter whereas a high spatial resolution would going to be longer. So, suppose there is a NOAA-AVHRR; NOAA is satellite and AVHRR is a sensor. So, if we talk about NOAA-AVHRR revisit time is almost twice in a day, because it is having coarser resolution out point 1 kilometer. But if you talk about say cartosat then its revisit time might be after 22 days because it covers a very small strip and an order to cover the entire globe it takes time.

Therefore, temporal resolution varies bit set different satellites. Radiometric resolution which is the precision of observation and a not basically accuracy that whether it is 6 bits data, 7 bits data, 8 bits data. Generally, now a day’s most of the sensors are having 8 bits data, but there are sensors which are having more data more width on radiometric resolution like NOAA-AVHRR having 11 bits data. So, if it is 8 width data which is quiet common standard one, then the values the pixel values can varies between 0 to 255; that means, total numbers of 256 values can be there. But if it is 7 bits then you know that it would be the value between 0 to 127 that means total number of value are going to be 128. And if it is 6 width data like IRS, time sensors were there were 6 bits data, so the value they barring between 0 to 63 total number is 64.

So, radiometric resolutions and as time passing the technology improving we are improving almost everywhere except may be in temporal resolution, because if we go for higher spatial resolution our temporal resolution that means, revisit time of observation becomes larger. So, this going to be a reverse fashion otherwise spatial resolution is improving, spectral resolution is improving and radiometric resolution is also improving.

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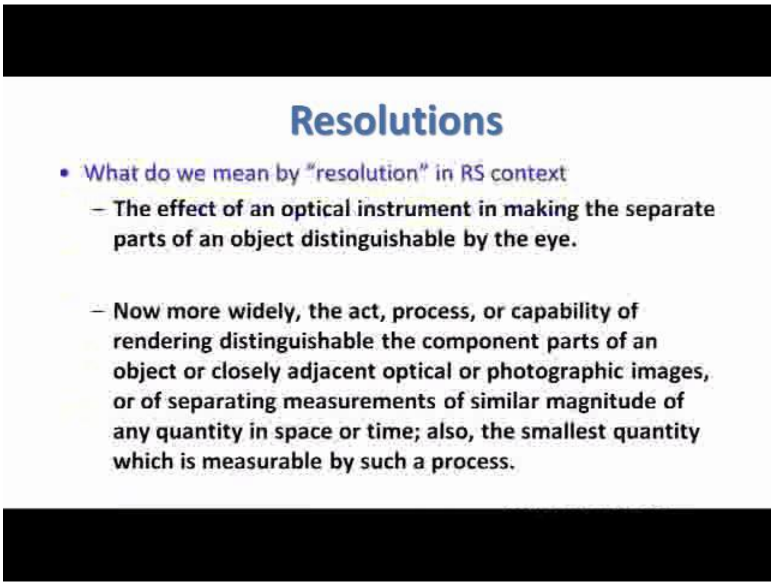

Now, basically when we come to the remote sensing part here, because lots of data in GIS is coming from remote sensing and that is why this component this theory or this understanding need to be. We have to spend some times to understand this one and the resolution because as I have said that digital elevation models which are here now this 2 digital elevation models have come from remote sensing sources, how how in remote sensing exactly which are the things which influence the spatial resolution which we see in details.

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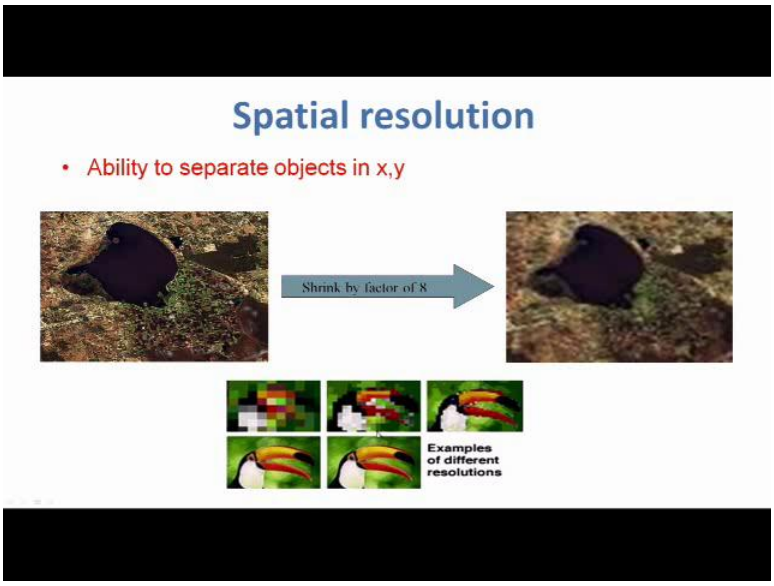

And as we have already seen that this is the availability the examples are here, that when you make a coarse resolution data this is how clarity will appears. And same with our photograph as well simple photograph as we can see, that if you go for coarse resolution nothing is basically visible there.

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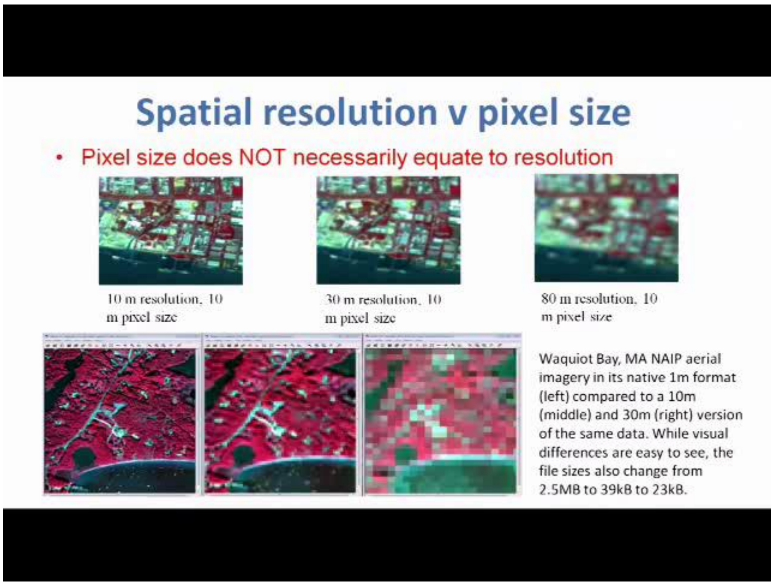

Same with the satellite images and also sometimes say this is show that pixel size is not basically I mean (Refer Time: 20:59) it is not always that pixel size is like a pixel size does not necessarily equate to the resolution, because nowadays this resampling or subsampling techniques are available. So, even the data has been collected you can change the pixel size, but that does not mean that you are going to change the resolution. This is what exactly here is.

So, when we you go in a reverse way like here you are doing subsampling; that means, like here a input image is this if you alternate pixel you may go for like this. Now you gone for coarser resolution again input image is this and again you read alternate pixel you may end up something like this. So, they are sampling resampling subsampling techniques are also available, but going backward is generally is not common, but people try to resample it to a smaller pixel size sometimes to fit with other dataset. But there is not going to improve anyway the resolution of your dataset it will only repeat in both direction x and y direction, but more value of the same input value of pixel. So, that is why it is said pixel size does not necessarily equate to resolution.

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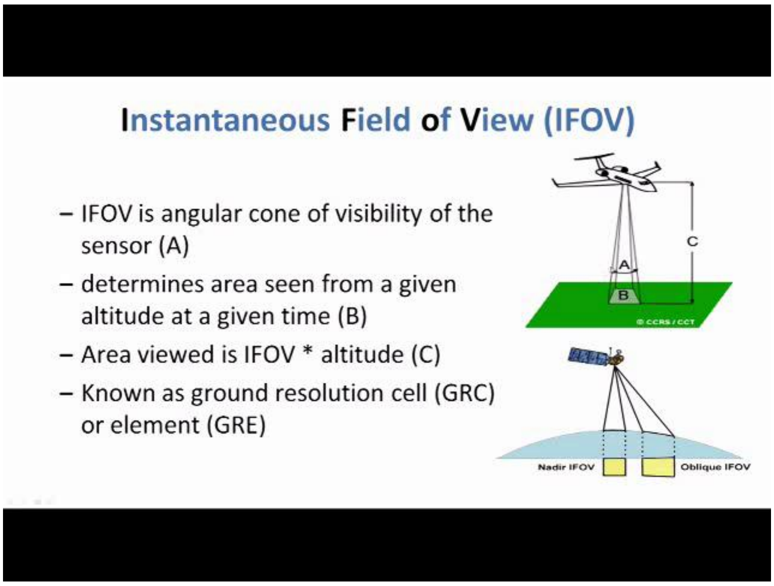

Now, because lot of data in GIS is coming from remote sensing, so there are one important term here is that is the IFOV which is instantaneous field of view. So, when data is collected instantaneous field of view is a basically solid angle, whereas the resolution which we assume is a square in shape. So, when it is created then those at the nadir view particularly just downward of the sensor it is IFOV is perfect in order. And as expected as indented, but as you go away from the sensor and it become off nadir or oblique then instead of getting exact square you start getting the rectangle and then complication is starts come. But when major generated we always assume that your pixel or cell is representing a square area.

So, the IFOV be this is the solid angle, whereas in the ground we assume is square or rectangle, basically is a square and then associated. So, there is why if your resolution relatively low or coarser resolution image then the curvature of the earth will play very important role. And on the edges these images which are covering a large area of the earth will have the problems on the edge and their resolution relatively the sharpness in those images will disappear relative or compare to the central part.

And this example can be seen with NOAA-AVHRR data, because the width or swath of a one sea is about 2800 kilometer. So, in the center of the image your representation of earth is a truly least square, earth part is represented as a square no issue, but when it goes on the side of the sea that there the curvature of earth plays a very important role. And therefore, you are covering the rectangular area which you are representing as a square area in an image and therefore these distortions are there and clarity of an image on the margin or in the border is not as good as in the center.

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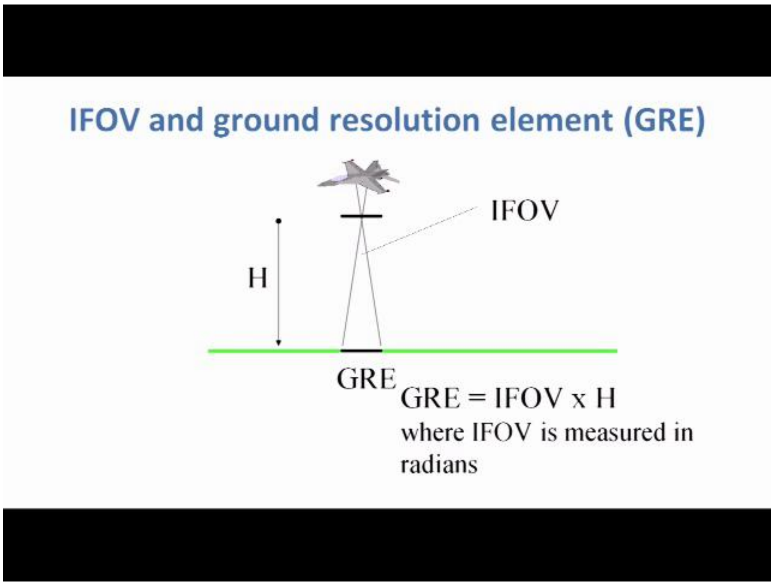

So, this ground resolution element is equal to IFOV and height. It depends on the height generally the earth orbiting satellites whether landsat, NOVAA, Cartosat almost all these satellite are orbitering around 940 kilometer plus minus 10 kilometer. So, they are you can consider height is almost constant, but if a very high resolution image is there then

IFOV and is going to be very small. And therefore, your ground resolution values are going to be distance or area is going to be small, what we call it as a higher spatial resolution.

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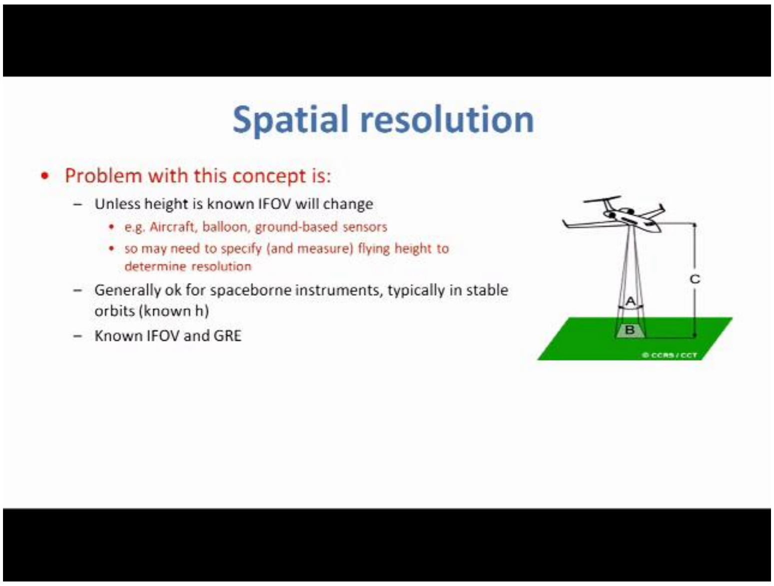

Here a example shown here, but when we go for a wide angle this is how it is happen.

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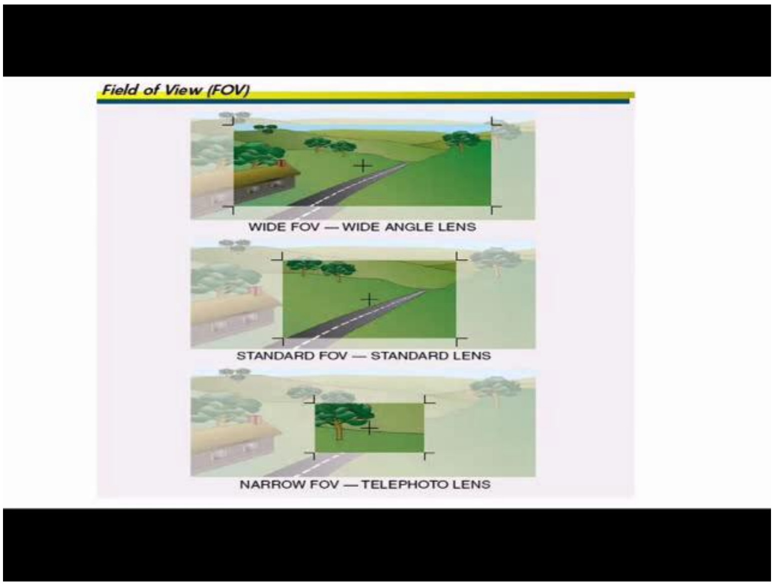

But when we go for a very narrow then we start seeing only a less distortion in an image and the other things will not come. This is field of view not in case of satellite image, but contour white is remains same. When you go in photography when you use the wide angle then at the it is basically area which curved area is being representing in flat area, in a flat film or photographic paper. But when you zoom it then this curvature or this thing this is sure it will not come. So, that is why this is important to understand IFOV height and ground resolution which is concern for us.

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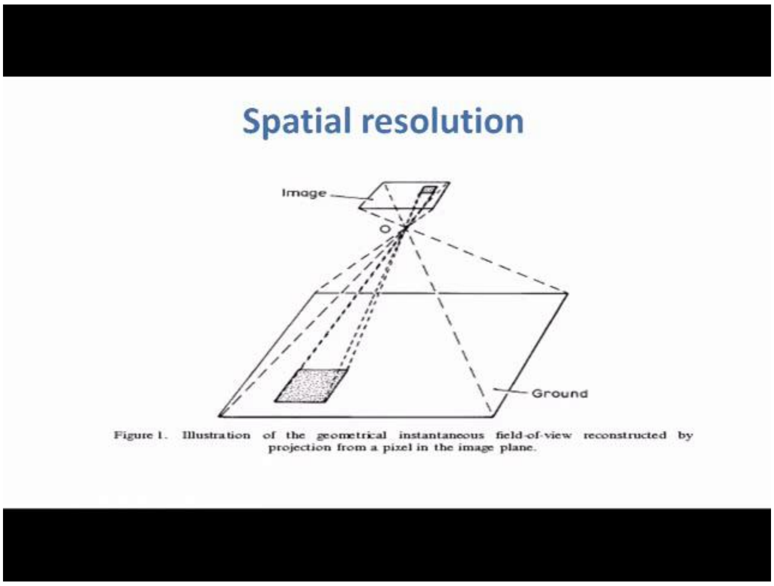

And here also through this geometrical instantaneous field of view is constructed that in your sensor this is how it is there, but on the ground this is covering this much of area. Now this is the last slide of this presentation is there is always a question that what this spatial resolution is appropriate for my area. And it is very hard to explain that depending on your project depending on your requirements once we choose appropriate spatial resolution, but exactly that appropriate.

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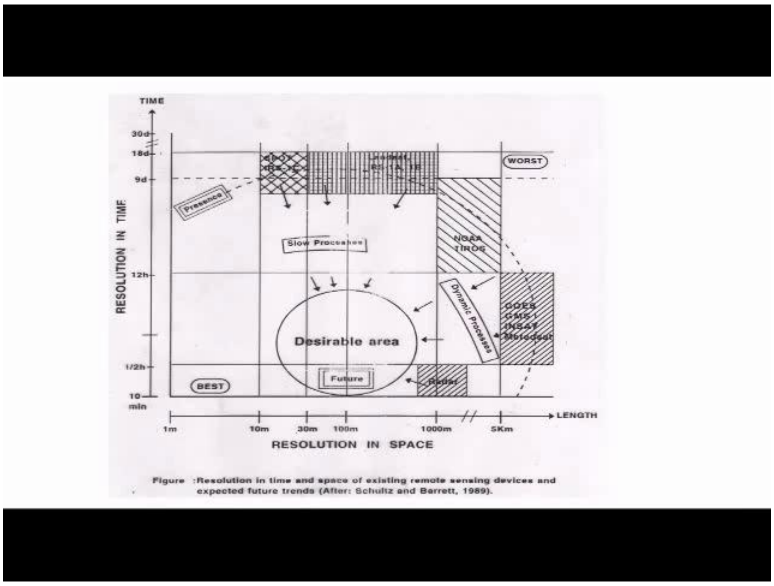

There is a blue graph or a figure was given by Schultz and Barrett in 1999. That for depending on different requirement of different projects which satellite data or which spatial resolution data are good. This is resolution in time this is the desirable area where at that time it was in 89 it was assume this is the area were all data will come. For example, if I say radar data at that time radar data resolution was around 1000 meter that means, 1 kilometer, similarly that presently this NOAA series of satellite data also having about 1.1 or that that kind of resolution.

Of course, you can desire at relatively high resolution also resolution at time that you desire images after even half an hour or each 12 hours would be there with the high resolution. And then you are having some other satellite like IRS now this or landsat, now latest is landsat eight ole series and their resolution definitely coming to about 30 meter or 10 15 meter here this region, so this has shifted this much. Now, but repeat cycle the resolution in time that is temporal resolution is still remaining there. So, as I have already mentioned that higher the spatial resolution lower is going to be the temporal resolution. The repeativity or revisit of satellite is going to be much longer.

Relatively coarse resolution like in case of NOAA data they may come after event every 12 hours and therefore you may have coverage twice in a day. With relatively coarse resolution data because they swath width the area of coverage of the earth is much larger and therefore repeat cycle is much shorter. In case of higher spatial resolution data the swath width even 11 kilometer. So, if I compare NOAA data it is 20000 kilometer with the high resolution data may be say 1 meter resolution data the swath width may 121 kilometer.

So, when a repeat cycle or repeativity or temporal resolution is going to be relatively very low when we compare with NOAA data. In the last I would like to mention depending on your project one must choose the appropriate spatial resolution of your data that is a satellite data or it is a digital elevation model. But one thing one must understand before you imply such data sets in any of such projects that what are inherent errors or problems are associated with base data, because as you know that errors propagates in GIS. So, we must know the errors which are already inherent errors which are already errors in input datasets, whether it is digital elevation model and your satellite data, also mentioned earlier that we must also have information about the data that is the meta data.

So, if you are using say this ASTER-GDEM you must know that what is the accuracy of ASTER-GDEM, how it has been acquired and therefore you must record all those details of your project. Similarly, if you are using satellite data say landsat eight data then you must know that which date seams you have used, what was the resolution which were the bands or a spectral data and all those details must be recorded so that whenever this question of accuracy and time and any other details are asked you must be able to answer those questions very accurately depending on having the information about meta data.

Thank you very much.