Geographic Information Systems
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Lecture-58
DEMs Sources, Limitations and Future of Digital Elevation Models

Hello everyone! and welcome to a new discussion which we are going to have on DEM sources. From where you can get DEMs of different resolutions generated using different techniques and also, we will discuss limitations and future of digital elevation models. So basically, we are coming to the end of utilization or applications of digital elevation models and of course very near to the end of this course.

But before that, I should close with this one that you know with the digital elevation model that without it, it is very difficult to work for a GIS or in GIS. So, it is one of the essential sources of information. You have seen in various discussions in previous and 10-15 lectures that how a digital elevation model can be exploited for different types of applications, many civil engineering projects, in earth sciences, in environmental studies, in hydrology.

Also, for these non-conventional energy sources or renewable energy sources like in solar or wind also. And I am sure that as new and reliable digital elevation models become available, people will exploit more. They will develop more bridges between different applications and of course GIS. So, what we can say in nutshell that the digital elevation model is indispensable without which not much progress can be done.

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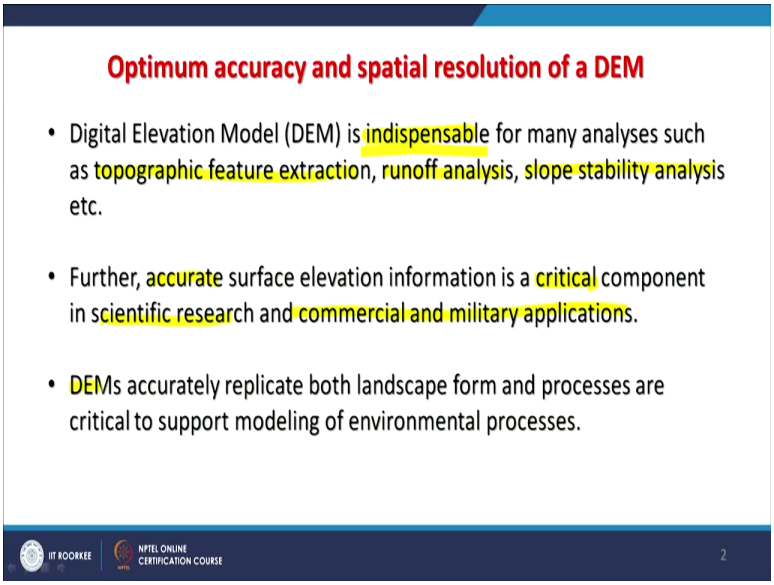

So, remote sensing data and digital elevation model; these are now very-2 important components or input components of GIS. So, basically what we do? As we have seen that topographic feature extractions; lot of features starting from slope, aspect, even to runoff analysis can be done through surface hydrologic modelling. And then one can exploit for slope stability analysis like in landslide hazard zonation and other things or also in soil erosion study.

So, one source of information that is digital elevation model, virtually n number of applications which we are talking now. So, for very accurate surface elevation information which is because if analysis is done on a digital elevation model which is not accurate and not reliable then any kind of results which are coming, one will not have a high level of confidence.

So, this is very critical component, that for scientific research and for commercial or military applications, this has to be very-2 accurate; digital elevation model as far as possible because 100% accurate will not be ever possible because that is the real word which is only one which is the 100% accurate. So, because ultimately it would be a model; it is a representation of the terrain. It is an abstract representation of the terrain.

So, there always be issues about accuracy, there are always be issue about the resolutions but nonetheless whatever is available which can be definitely exploited nowadays for various

applications which we have already discussed. So, DEM accurately replicate both landscape form and processes are critical to support modelling of environmental processing.

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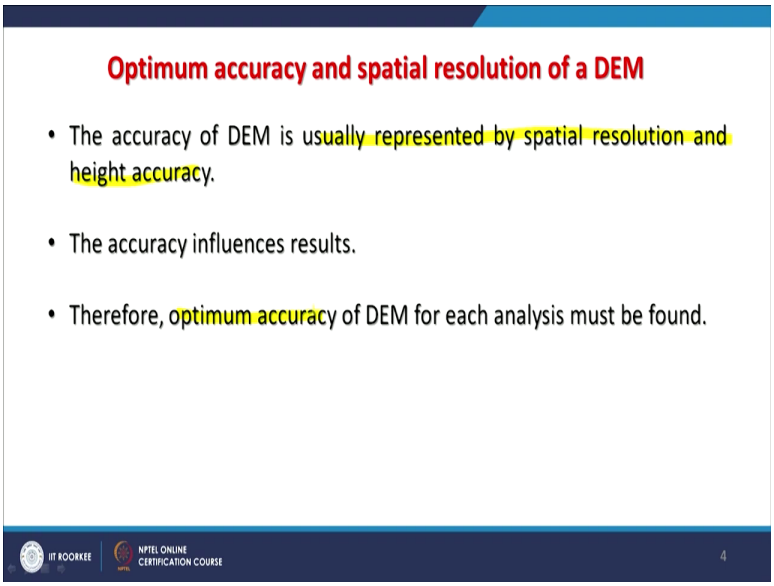

So, various applications are there whether somebody is planning an infrastructure network, conducting a military intervention, mission or for an unknown terrain or analyzing terrain features for oil or gas or water, minerals. Everywhere you require very accurate representation of the terrain. And generally, many such applications analysis requires a high accurate. Now, these are relative terms; accurate, high or high spatial resolution. We started with 1-kilometer spatial resolution DEM of USGS which was generated using survey toposheets.

Now, we are talking about digital elevation models of 5-meter, still discussions about accuracy and spatial resolution will keep happening. But whatever is available, one should exploit to the maximum and create useful and reliable outputs as far as possible. So, this accuracy of DEM usually represented by spatial resolution and height accuracy. And this accuracy influences results of course and therefore optimum accuracy.

So, this is more appropriate term here rather than absolute accuracy, we should look for optimum accuracy for DEM for different kind of analysis.

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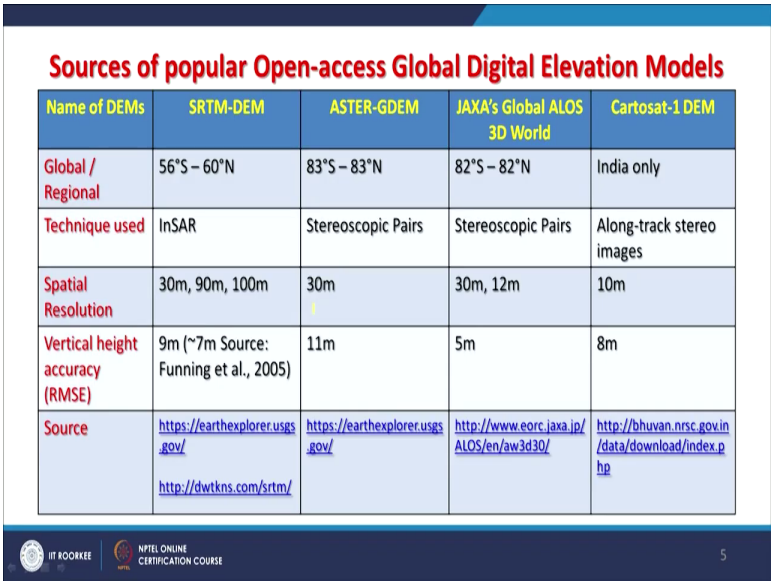

Now the sources; which are the sources from where I can get digital elevation models. So, the sources which I am going to discuss here or have been discussed mention in this table are the open access, open sources which through net you can find. And of course, if you want your own digital elevation model with a high accuracy and high spatial resolution then one can buy the stereopair data like from CARTOSAT or other satellites and can generate using and this photogrammetric technique to generate digital elevation models.

So, that possibility will always be there. And we can even go for higher and higher spatial resolution digital elevation model. But what we are discussing the open access which are available free of cost and which has been generated or put on different portals by different organization. So, one has to be careful about while searching all this whether a particular digital elevation model is global or regional or that kind of thing for some specific country.

So, global parts are important. Like for example SRTM DEM. Now, SRTM DEM is a global digital elevation model and whereas like ASTER DEM is also a Global GDEM; that is global digital elevation model from ASTER satellites and this ALOS 3D world; this is also global but our CARTOSAT DEM is regional and only for India. So, that one has to know before going for that data.

Another important thing one should know for which area whether it is a flat area or hilly terrain, he is going to use digital elevation model. We discussed once in a lecture that when we analyze different digital elevation models of 30-meter resolutions of different kind of terrain, we found different digital elevation models having different accuracies. So, accuracy will depend how they have been generated and for some areas, this INSAR based digital elevation models like SRTM may be very good for plane areas.

But if you go in hilly terrain like Himalaya then there will be a question mark relatively with the INSAR data. Whereas the stereo data are very good for hilly reasons but may not be that good in plain areas or completely flat areas which are without land features or landforms, there digital elevation models like ASTER DEM which has been based on this stereo pair technique may not give good results.

But they are giving good results for hilly region. So, that is why I said for which area you are going to use accordingly you choose different. They are all available for different resolutions like all are roughly available for 30-meter resolutions. Even CARTOSAT digital elevation model only for India, you may get a 10-meter. Now, vertical height or that is the vertical resolution; of course, this is all in meters, 1 meter least count.

But the accuracy part, it is always a sort of that is the mandatory information by these organizations who have developed different digital elevation models to provide that information too because in your scientific research or other domains, you require that information also. So, like if I take this SRTM, there is about 7-meter by the person who has analyzed the data or the organization which developed this SRTM DEM, they claim 9-meter.

And then ASTER GDEM is 11 meter in that sense but again, this will depend where you are located in hilly region or plane region. With this analysis or in this table, an average value has been given. And then this JAXA Global ALOS 3D World site from there you can get a 5-meter. So, this is providing a very good vertical accuracy as well. Now, these are source information's about from where one well known portal which is Earth Explorer and this is also available.

ASTER GDEM, SRTM DEM; all are available on Earth Explorer. Then on the JAXA site, you can get this digital elevation model and then of course through BHUVAN, you can get Indian one. I think now they are not providing 10-meter. They are providing now at 30 meter, maybe some reasons I do not know.

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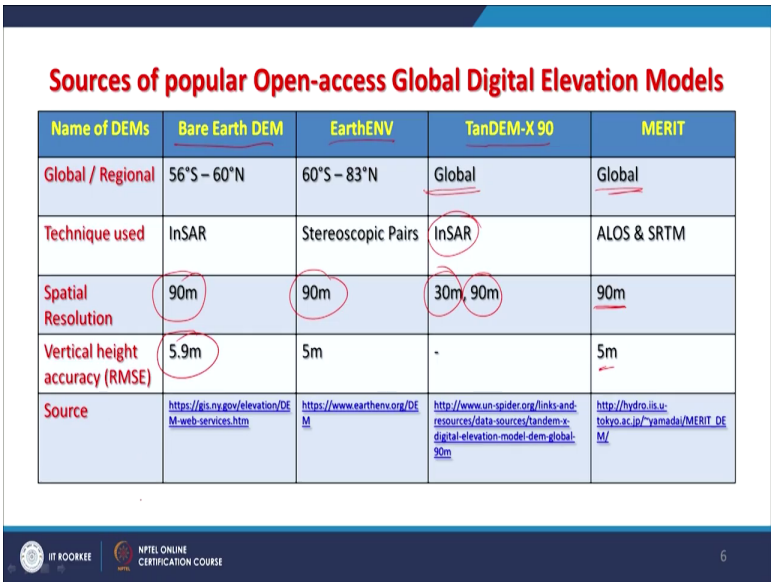

Now, further on this which we have just discuss about this that there are many other sources, may not have the global digital elevation model but regional one. So, like Bare Earth DEM; you recall this discussion Bare Earth because when we discuss about this you know laser-based techniques like radar-based techniques. where we discuss this Bare Earth DEM because other digital elevation models are representing top of the surface including features.

So, when you minus features then it calls Bare Earth. So, this Bare Earth DEM is having vertical accuracy 5.9, 90-meter resolution only. And then again 90-meter; this is EarthENV. Then TanDEM-X; again, it is available 30-meter, 90-meter. And this is INSAR based; the important point is that it is a global one and the MERIT is also global one but it is a 90-meter, 5-meter. And these are the names of the portals or addresses of portals are given here which one can definitely access.

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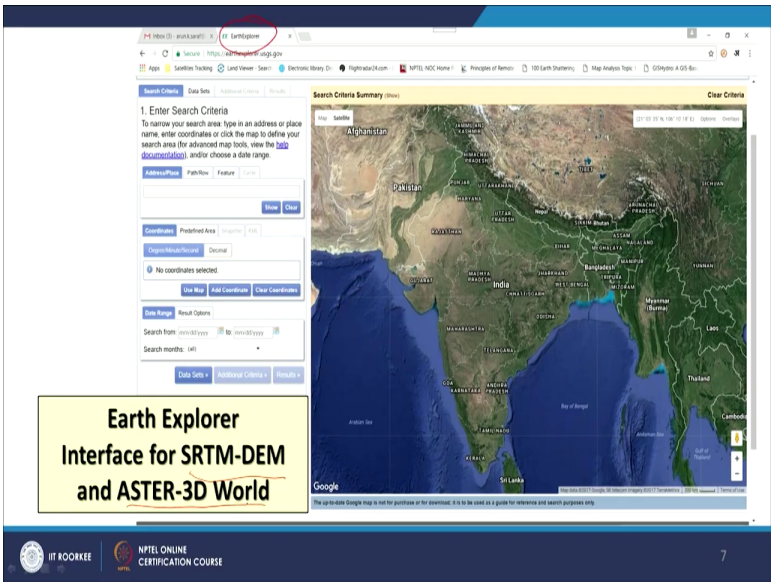

Now, this is thus you know screenshot of that Earth Explorer site which you can see here, very easy to get the data. You just put these details here and very easy to navigate here. And then you start getting the data and you get the link then easily download that one. So, you can get from Earth Explorer, SRTM DEM 30-meter, 90-meter, 1-kilometer. ASTER 3D WORLD DEM which you can get again, of 30-meter.

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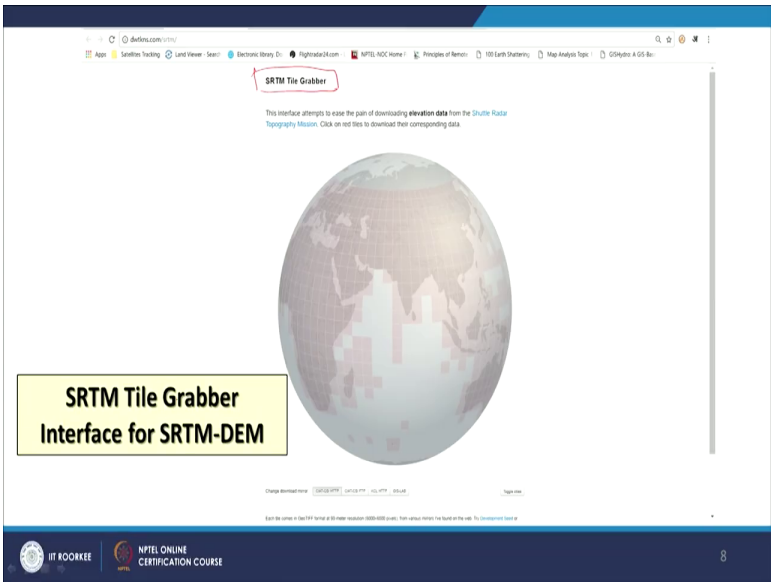

Plus, many satellite data are also available from earth explorer. This is one of the best sites I have found for such kind of data. There are other like SRTM Tile Grabber is also there where you provide details little differently and individual tiles, you can select if you know and then

download. So, this is SRTM Tile Grabber interface for SRTM. Same datasets you may find on various sites.

So that does not mean that if one side is different, the different dataset. If it is SRTM DEM almost in all sites, you will get the same dataset. So, this was the JAXA one also, there you also get.

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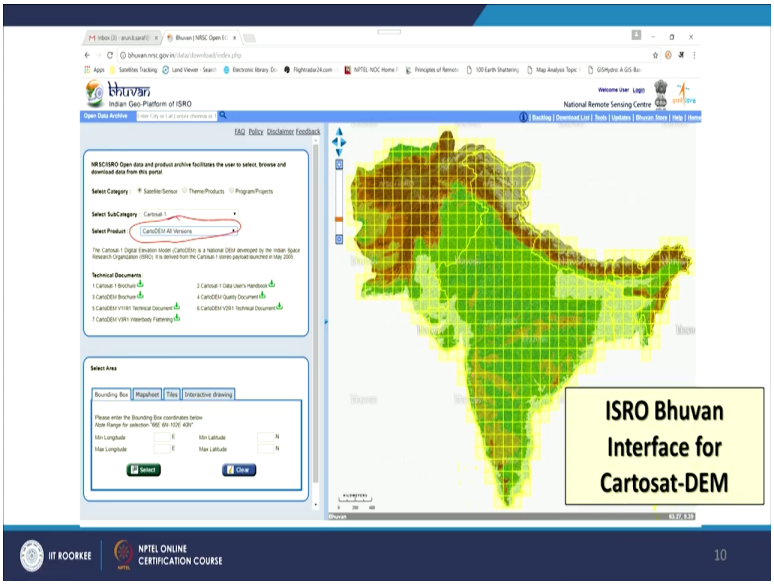

And then like this is Bhuvan; not only you are getting tiles for India but for subcontinent also and there it is also relatively easy to navigate that you choose like CARTOSAT of all versions, I have chosen here and when you get, this grid will be available. You select individual cell of this grid and you get this data or you can provide your latitude, longitude and then it will provide you what tiles would cover that area and you get the link, you can download the data free of cost.

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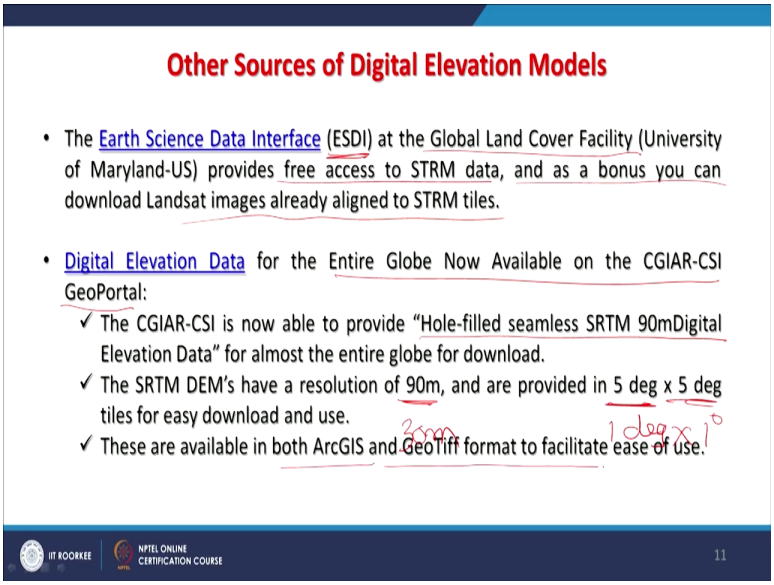

There are other sources of digital elevation models like Earth Science Data Interface (ESDI), used to be very good earlier, popular one but a lot of changes have happened. Nonetheless this site is still available which is a global land cover facility which is run by University of Maryland, provides basically free access to SRTM data. As a bonus, you can download Landsat images already align to SRTM tiles.

So, for the same tile, you also get a satellite image as well. So, you do not have to you know organize the things. Things would be georeferenced for the same tile; you get the data and of course the digital elevation data for entire globe now also available on CGIAR-CSI Geoportal as well. So, a lot of sites are coming; very friendly sites.

Recall that errors in SRTM so this hole filled or void filled seamless SRTM of 90-meter resolution, even nowadays 30-meter from various sites can also be acquired. You may get 1-degree tile or 5-degree tile. If its resolution is relatively coarse like 90-meter then tile size will increase; that is 5 degree * 5 degrees. If it is 30-meter then the tile size will have 1 degree * 1 degree likewise. So, there are various sources are available and both these available in ArcGIS and GeoTIFF format to facilitate ease of use.

Because there are already georeferenced and I prefer always downloading in geoTIFF format. So, if I want to use in any other software, I should not have any difficulties whatsoever. ArcGIS or popular softwares will always accept different types of formats for these grid data sets.

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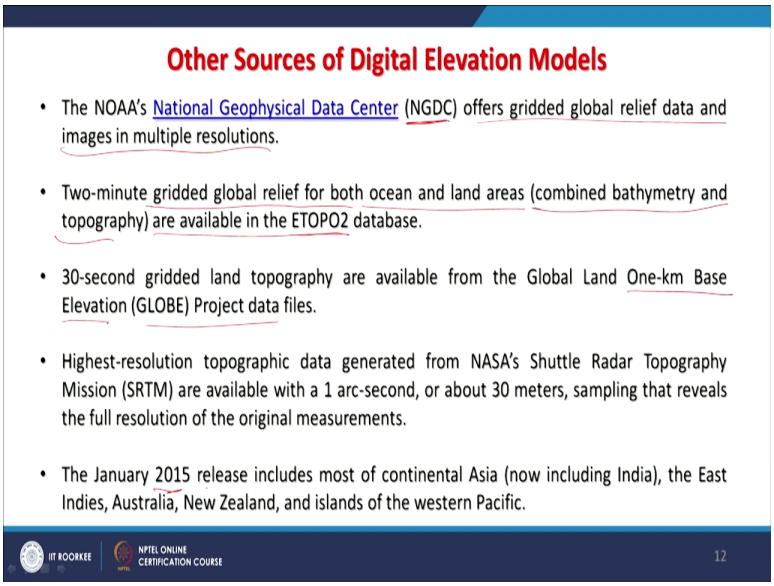

Now, another source of information can be NGDC which is the national geophysical data center which offers the gridded global relief data, images of multiple resolutions. Rather than in 1-degree, you get to more detailed one; that is the two-minute gridded global relief for both ocean and land areas. You also get the bathymetry data, topography; all are available of this ETOPO2 database that is also there.

And now 30-arc second gridded land topography are also available from one-kilometer base global project data file. So, lot of sources are there. Now depending what you are looking for, what you are going to use it. So, starting from one-kilometer to you know 10-meters; that means the 1000-meters to 10-meters, you are having digital elevation models generated from different techniques are available on net for you to download and utilize them.

Of course, their accuracy will depend on resolution as well as which part of the world, how the terrain is. So, in January 2015, this release of includes most of this you know from this site the Asia now, included India, the East Indies and Australia, New Zealand, Islands of Western

Pacific; all for that the data is available. Now, we reach to a section of digital elevation model which is about the limitations of them.

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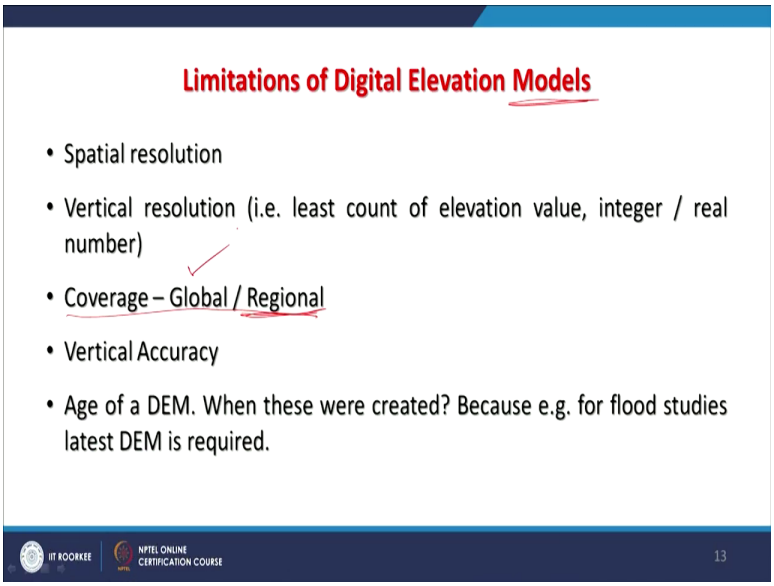

So, first limitation is in the word itself that is the model because model is an abstract representation. That is not the real world represent. Real world is really on the one-to-one scale. So, whenever there is a modeling is done to anything then some errors or limitations will always be there. So, one of the limitations which have been always in discussion is about spatial resolution. As I mentioned that when we had only one-kilometer spatial resolution digital elevation model at global scale, we were saying that it would have been better if we get a spatial resolution digital elevation model instead of a 1000-meter, if we get 500 -meter that would be wonderful.

But then from 1000-meter, we came to 90-meter. For some time, people were happy then again, they started looking for higher and higher spatial resolution. So, this you know desire for higher and higher spatial resolution will always remain whether it is a digital elevation model or related with the satellite images nonetheless. Now, vertical resolution or that least count of the elevation value that is equally important.

So, before you download any data, the best thing is to read about that particular dataset spatially the meta files and details; how this has been generated, what is the accuracy part, how this

vertical resolution has been handled? So, lot of your reliability of your studies will depend on the input of this information. And whether the coverage is global or regional. If you are working on a small area then it is fine if you are available regional.

Because the best part if you are downloading a dataset which is a global because if the particular data set available like a GDEM or SRTM then thousands of people or millions of people world over are utilizing that data and they have analyzed, they have checked from every point of view. So, that kind of information which you would have against a global digital elevation model which you may not have for regional.

For example, if I say about CARTOSAT so, whatever this NRSA or ISRO people will say, we have to believe because that is not globally available. If that dataset CARTOSAT DEM would have been available for entire globe then world over people will use that data and then they will comment on the accuracy of the data. Not only the spatial resolution but the accuracy, vertical accuracy as well. So, that opportunity will not be there or that information will not be available to you if you are using regional one.

But that would always be available to you if you are using the global one. Now, age of DEM; sometimes it can be very-2 useful if I am detecting a change detection study. While discussing about erosional features and other things, I mentioned that if I am having two digital elevation models of having say 20 years time difference then I can know that where and how much changes have occurred. You know assuming that these both digital elevation models which are have been used for this kind of calculations having relatively good accuracy.

But if I am not doing a change detection study, I would like to use this DEM along with say satellite data or for some any other purpose then it has to be latest. If it is latest then for various applications, it would be really very useful and the output which I will create will be highly reliable like in flood studies because every year along the rivers if floods are occurring, they will keep changing the landscape or you know there might be some shifting or changes in the meanders or shape or geomorphology or fluvial geomorphology of the river.

So, if I am having a latest digital elevation model on which I estimate the flood scenario then I am going to have a quite good accurate but if I am having 20 years old digital elevation model then. So, age is also in some cases limitation. May not be in many geological studies or many other studies but for many civil engineering projects also, age of digital elevation model can play very-2 important. So, before employing a digital elevation model for such projects or such study, one should also know when it was created?

How it has been created? What is the accuracy? Apart from that when it was created also becomes important in many studies.

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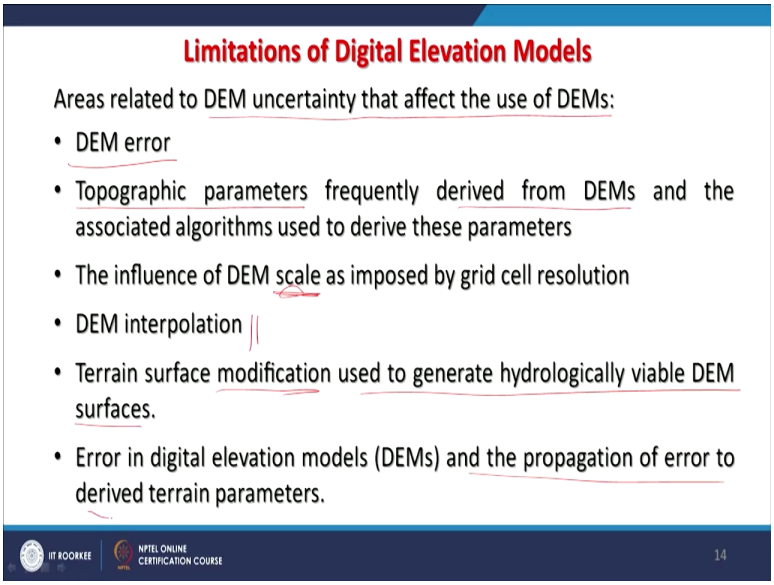

Now, further in these limitations of digital elevation models that areas related to DEM uncertainty that affects the use of DEMs. And also, we have used one this while discussing about the accuracy of a digital elevation model, specially how to assess then we said that these are you know spatially vary; the accuracy part varies. So, uncertainty will also vary; that means within a digital elevation model file, some part may have very accurate representation and some part may not have very good accurate representation of elevation against those particular cells.

So, we have to be careful while employing digital elevation model. So, what are the important; DEM errors, of course they play very important role. Topographic parameters frequently derived from digital elevation models; slope, aspect is starting and then you end up with the surface

hydrological modeling and sediment yield and other things. So, all these will depend because they are dried from digital elevation.

So, this error will influence our results which are based on digital elevation. Influence of DEM scale is imposed by grid cell resolution. A very coarse resolution digital elevation model if it is being used as a large scale, you will have problems. Vice versa is also true. So, one has to struck a optimization with the spatial resolution and the scale. Nowadays, most of the things are doing being done on digital platforms on screen.

So, sometimes only at the time of display, scale will matter otherwise as long as the data inside the computer, scale will not matter. And of course, the DEM interpolations; which technique it has been employed to interpolate using the point heights that also plays very important. Though we have already discussed in detail that how to assess which interpolation technique is best suitable for that set of data before I go for interpolation.

So, that assessment one can always imply. Now also that terrain surface modification keeps happening and which we use in hydrological analysis. So that is why I said that the age; basically, these modifications are related with the age of a digital elevation model because we know that these things keep happening. So, terrain surface feature modification used to generate hydrologically viable DEM these surfaces.

And error in digital elevation models and propagation of the error to drive terrain parameters. Remember that this point will further come in our last two discussions especially the sources of errors in GIS that you know basic understanding about the errors in GIS is that error propagates in GIS. And therefore, I have been saying throughout this discussion or in this course that check for errors after each and every step of your operation.

And if found, correct it there yourself. Do not leave for others to correct it because error propagates in GIS therefore even if I am using a digital elevation model, I must be aware about what kind of error or accuracy and then this propagation should be avoided as much as possible. Because errors should be contained, they should not be allowed to propagate in GIS. The

purpose of GIS is not to you knows introduce errors. The purpose of GIS to keep errors at the minimum.

Because if my output becomes highly unreliable then no use of doing that exercise. So, now different applications may require different spatial resolution DEMs. What it means basically for all studies, you do not require always high spatial resolution digital elevation. Sometimes I have used one-kilometer spatial resolution digital elevation model. Sometime I would like to use even 5-meter spatial resolution digital elevation model. So, various applications will require different spatial resolution digital elevation.

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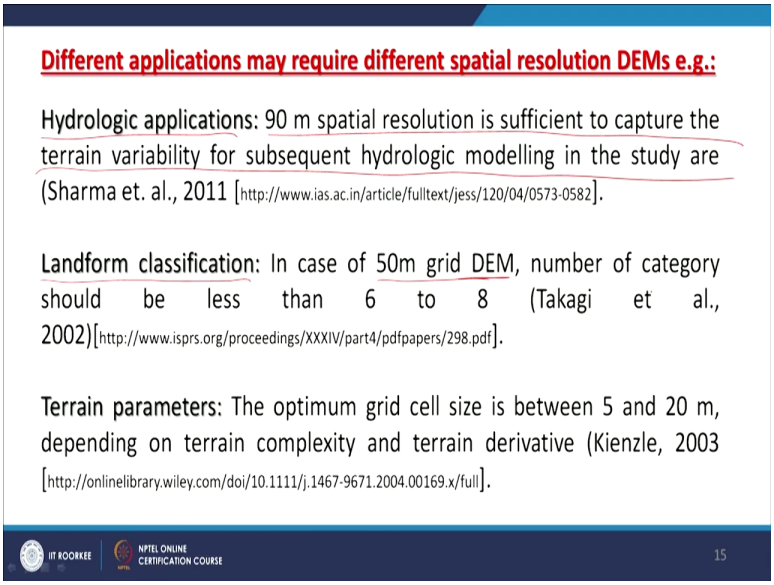

So, for like hydrologic applications, 90-meter spatial resolution is sufficient to capture the terrain variability for subsequent hydrologic modeling in the study area. So, people have assessed this thing and they found that this is optimum. Fantastic, no problem! Even in freely available 30-meter but why to go unnecessarily for hydrological applications which involves a large area. So, for landform classifications in case of 50-meter digital elevation model, we can still categorize things. So, this thing again is there.

For terrain parameters, the optimum grid cell size is between 5 to 20-meter depending on the terrain complexity and of course the application and terrain derivatives which product I am trying to derive. But basically these are the judgments or opinion of different authors which they

have written in their publications. You may find little different experience but more or less one would reach to around those figures of those spatial resolution.

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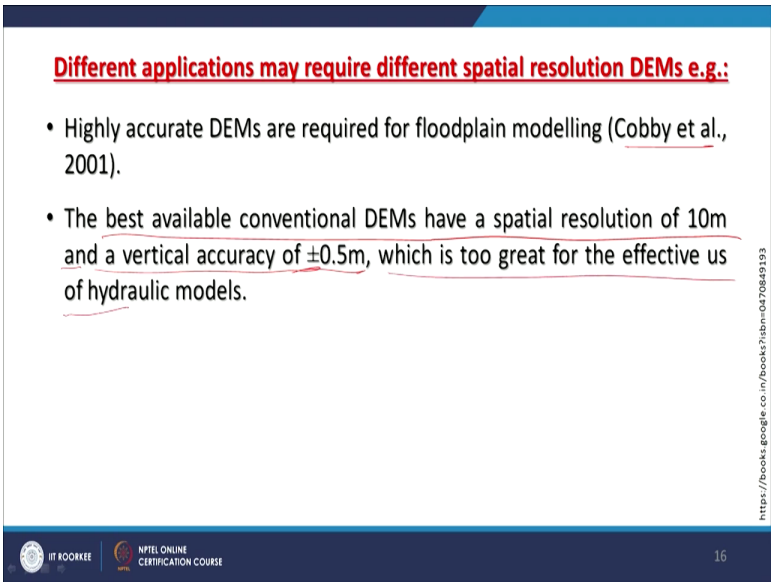

So, very high highly accurate DEMs generally are required for flood plain modeling because you know you really require a very high-resolution DEM because it affects the life and you know the infrastructure. So, even a one-inch extra water or one-foot extra water can create havoc in any therefore you require a very accurate digital elevation model. And also, whatever the best available, one can exploit and then assess the quality of digital elevation models.

So, the best available conventional DEMs have a spatial resolution of 10-meter, a vertical accuracy of plus minus 0.5 meter which is too great for the effective us for hydraulic models if it is available. So, if it is not available, we cannot do anything.

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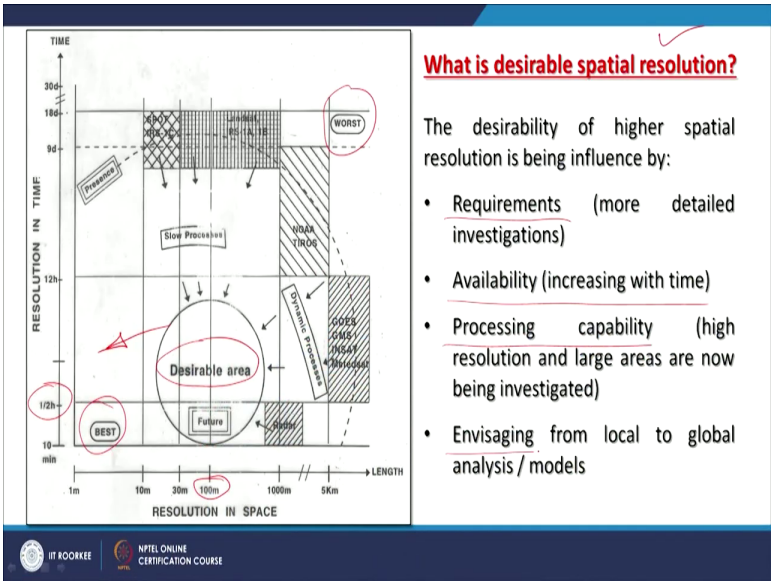

Now here this spatial resolution, sort of a last discussion on spatial resolution and few years back, I found this a nicely drawn figure, though here the quality may not find very good but still this is what very nicely depicted with the time how things have changed and what are the desirable spatial resolutions for satellite data. Same we can link with the digital elevation models as well.

Like here few years back, even 100-meter was the desirable and you know the resolution in time; how frequently the data should be available was you know like every half an hour people wanted but what was available where at this stage that if I go then, they say that this is the like 5-kilometer and above spatial resolution is the worst scenario. The present scenario presents the best one was here but you cannot have digital elevation models for any part of the globe on very frequently basis because it requires resources to generate a digital elevation model.

So, this discussion about spatial resolution will keep happening as new datasets becomes available, new applications comes and this will keep going on and this desirable the area which is shown here in this figure will move here and this may become very narrow in that sense that I require only this now but this will keep happening all the time.

So, yesterday whatever was the high spatial resolution is no more now high spatial resolution. That is now considered a coarse spatial resolution for example 90-meter spatial resolution digital

elevation. Few years back relatively as compared to 1000-meter, 90-meter is really high spatial resolution but people now, they call as 12-meter or 5-meter is high spatial resolution, not even 30-meter as a high spatial resolution.

So, this keep changing; it is a relative term. Now, the desirability of higher spatial resolution basically is getting influence because of the requirements. More and more detailed investigations are required, are happening and will keep happening. Of course, it depends on the availability so availability increasing with time. More options are available.

Not only on the USGS Topo digital elevation models but I have shown from several sources, you can get digital elevation mode and for many countries. many other options are also there because those are not global digital elevation. Now, our processing capabilities is also increasing and therefore our machines, computers, software are capable of handling high spatial resolution digital elevation model that means they are capable of handling large files. Earlier they were not there. things used to become very slow.

So, therefore you know these things goes hand in hand; more the high spatial resolution data becomes available, same time your computer technology is also improving, software technology is also improving and all these are bringing better and better opportunities to work. Now, envisaging from local to global analysis models, people are expanding their areas. They do not want to now concentrate only on the local studies, they want to do it at continental scale even at a higher spatial resolution.

So, you require fast machine, you require that kind of accurate high spatial resolution data as well.

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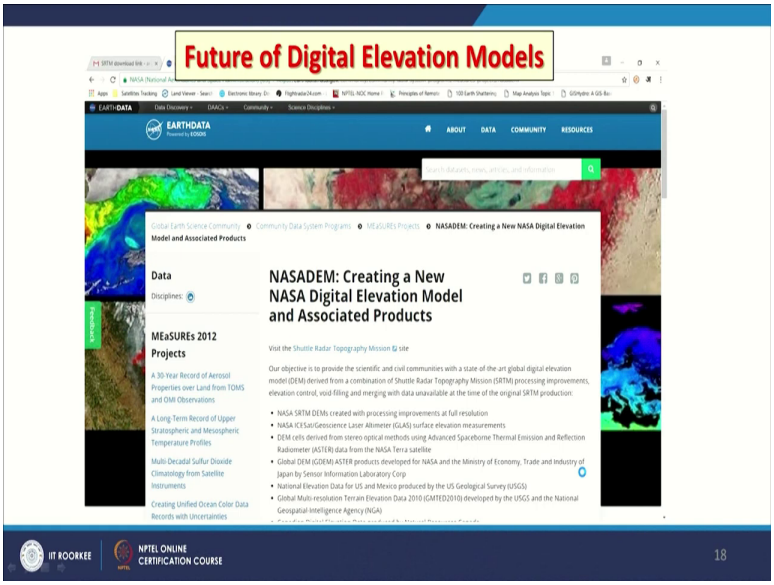

Now, little bit about the future of digital elevation models. People are thinking now for of course high spatial resolution digital elevation model but NASA is thinking in creating a new digital elevation models and associated products. And of course, it is going to be on what I would say, very high spatial resolution and that to on a global scale and maybe of 2-meters or 5-meters.

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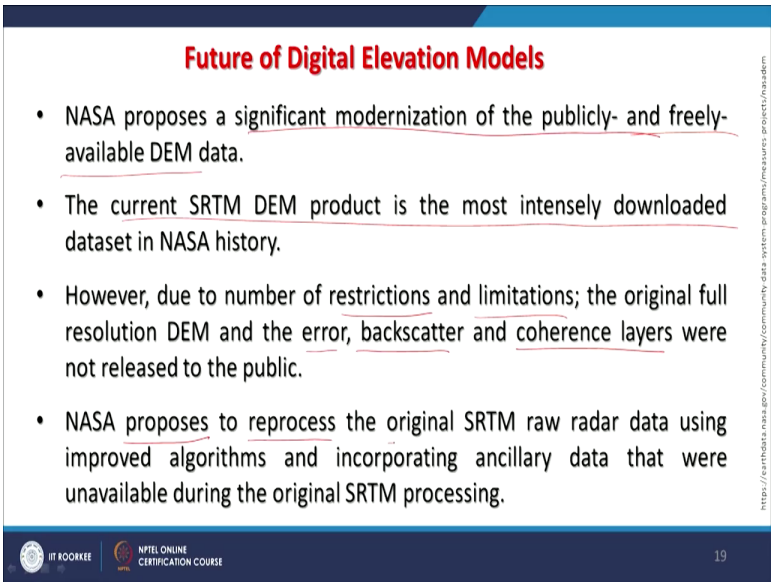

So, it is proposed that is significant modernization of publicly and freely available digital elevation model, may take few years nonetheless things will come. Like current SRTM DEM product is most intensely downloaded data sets because it is available at different resolution; one-kilometer, 90-meter, 30-meter. So, people are very familiar and comfortable with that

dataset. However due to number of restrictions and limitations, the original full resolution DEM and error back scattered, coherence layers were not released to the public because these are related with your SAR Interferometry.

So that information was not available or not released. Now, it is proposed to process or reprocess the original SRTM data which was collected through a mission with improved algorithms and incorporating ancillary data that were unavailable during that time of SRTM processing. So, even if that reanalysis is done with improved algorithm with the SRTM data collected then we can have again a high resolution or better quality digital elevation model; quality means here accuracy I am talking.

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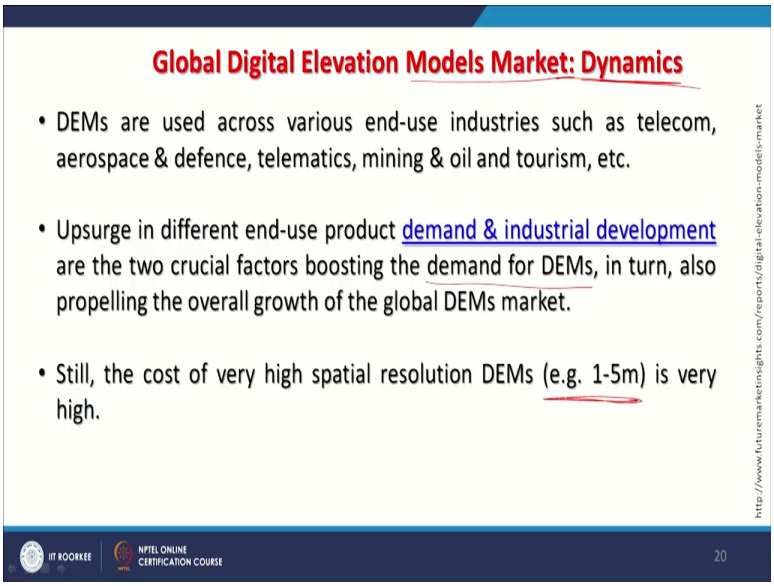

Now, what is this market and of course the dynamics; it is ever changing. So, DEMs are used across various end-use industries such as telecom, aerospace, defense, telegram, mining, oil etc. Of course, in research and education. And upsurge in different end-use product that is the demand in industrial development are the two crucial factors which basically forcing or compelling the demand of better and better digital elevation models. When I say better, I means highly accurate and maybe high spatial resolution DEMs.

So, DEM market is still very big and people are looking somewhere about spatial resolution. Of course, accuracy, they too are looking for high and high.

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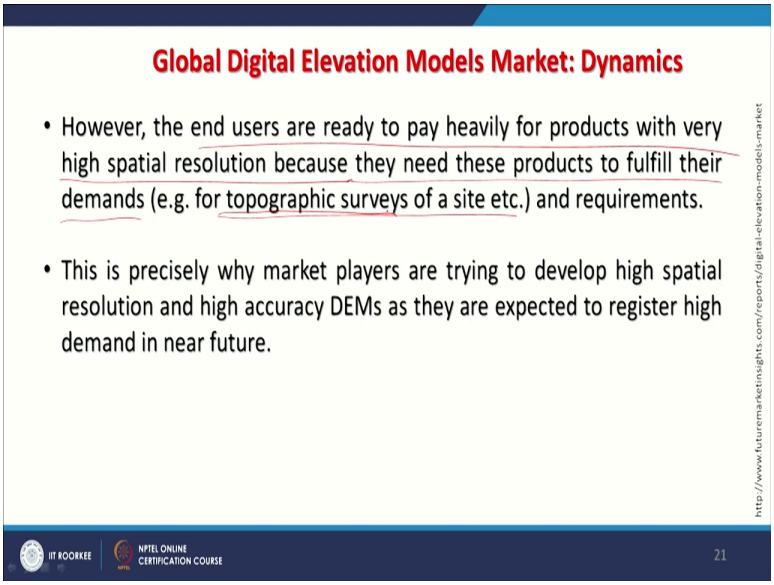

So, the end users are ready to pay heavily for products with very high spatial resolution digital elevation models because they need these products to fulfill their demands. What are their demands for topographic surveys of a site or local requirements? For many-2 detailed service, they require a digital elevation model at a very high spatial resolution. So, that area is always will remain open for development.

Because locally these might be required. High spatial resolution digital elevation models may not be very useful for continental or global scale study but for local scale studies whereas for certain project things are required. So, people would like to replace these topographic surveys and would like to have a high spatial resolution digital elevation model. And of course, the precisely why market players are trying to develop high spatial resolution, private agencies as well, high accurate DEMs as they are expected to register high demand in near future.

And the quality and availability of remote sensing data that has tremendously improved in last few decades. So, that too because many digital elevation models which we have been discussing, their basis is remote sensing data. So, as that technology is improving, this technology or this output product is also improving.

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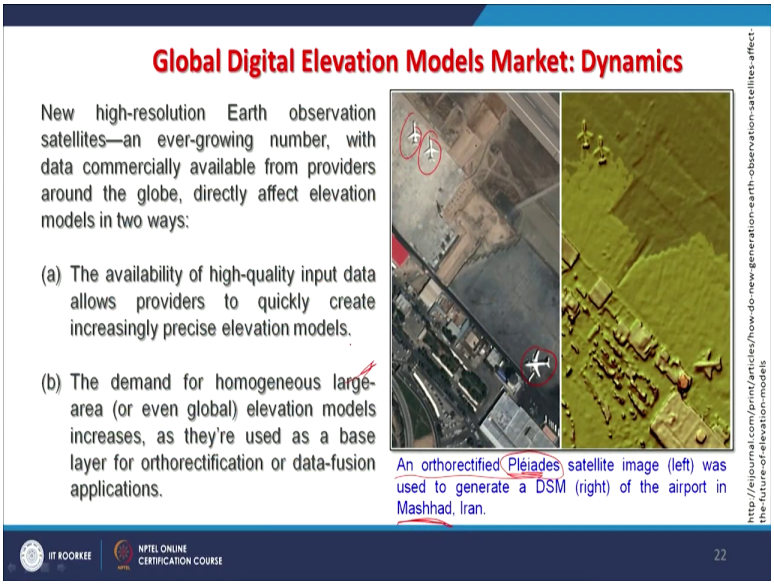

Now with high resolution earth observing satellites as I have said which is ever growing number, many-2 countries are having their own satellites and they too are producing you know data at high spatial resolution. For example, here the products are available where you can see individual aircrafts very clearly, individual trees, houses that this is of course an orthorectified Pleiades satellite image.

On the left side which you can see is how much details are there. And then a DSM; digital surface model has been generated for the airport in a city which is Mashhad at Iran. Luckily, I have visited that place. And availability of high-quality input data allows basically providers to quickly create increasingly precise digital elevation models. So, the speed is also very much in certain projects maybe of high demand and you know the demand for homogeneous large area.

So, once it is developed for local, people start thinking regional and then finally they start demanding for global scale digital elevation models at very high resolutions and of course with high accuracy. So, quality data people are looking.

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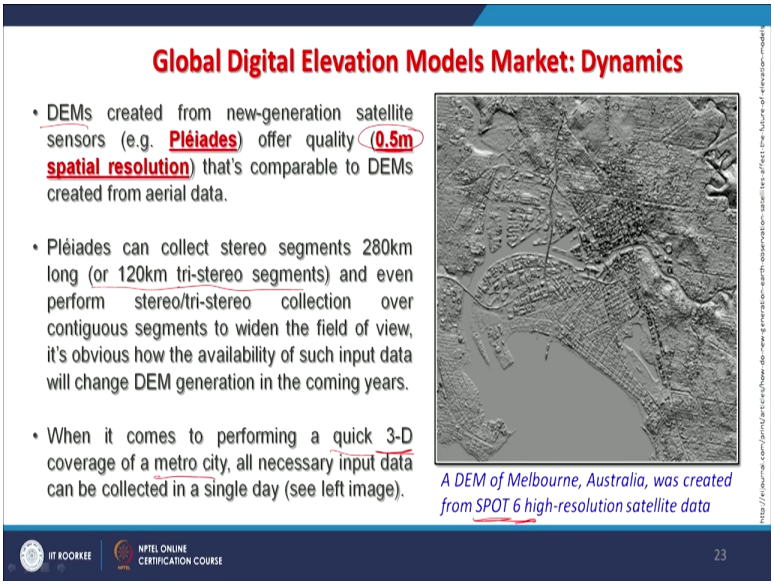

With this satellite Pleiades, one can expect even 0.5-meter; 50-centimeter digital elevation models are possible with these datasets. As you can see that what kind of detail it is there. These are some sample pictures. This is from SPOT 6 high resolution datasets and this Pleiades can collect stereo segments of 280 kilometer long and of course 120 kilometer in tri-stereo segments and therefore creating a digital elevation model with such things becomes possible.

Only you require a very sophisticated algorithms as well as expensive software to generate but things are being done anyway. And then quickly one can generate a 3D coverage of a metro city and all necessary input can be collected in a single day like here though, it is the example of SPOT 6 but in future, we will be also seeing a digital elevation model at 0.5-meter resolution coming from Pleiades. So, with this, I end this discussion. Thank you very much.