Geographic Information Systems
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Lecture-33
Different Map Projections

Hello everyone! and welcome to new discussion of this geographic information systems course. And in this one, we are going to discuss different map projections. Again, it is also very important topic of GIS because we have to handle different map projections. So, before we go for details about different map projections, first I will like to discuss what is the need of having different map projections. Why it is required?

As you know that earth is not perfect spheroid. Though it is a 3D model but it is not perfect spheroid, one. Second point is that each country having its own political boundary and located uniquely on the globe. So, whenever we have to create a map which is from 3D to 2D and that means that curved surface or curvature of the part of the earth I am going to make flat and when I do it, making flat for my own country then I want that overall shape of my country as it is located on the globe should be represented in true shape. It is a true shape.

And if shape is perfect then the size or area of my country will also be accurate but if shape is distorted then area of my country is also going to be distorted. So, what I am trying to say that though there is a map projection which is called universal marketer projection or UTM; universal transverse marketer projection, though the word universal has been used but that too is also not universal. So that means that since each country is located uniquely on the globe, each country is having its own width and height on a globe or an extent.

Then each country would like to have its own true shape and true size and therefore they have developed their own map projections. Many international disputes between 2 countries are many times due to the different map projections which are being used by 2 neighbouring countries and one say that mine one is accurate, the others one is inaccurate and vice versa. And therefore, many disputes are because of simple map projections. So, it is a very-2 challenging thing but equally important for measurements also.

So, whenever we do the measurements like length, perimeter or area, we have to be very-2 careful about the map projections. So, right selection of map projection is very-2 important.

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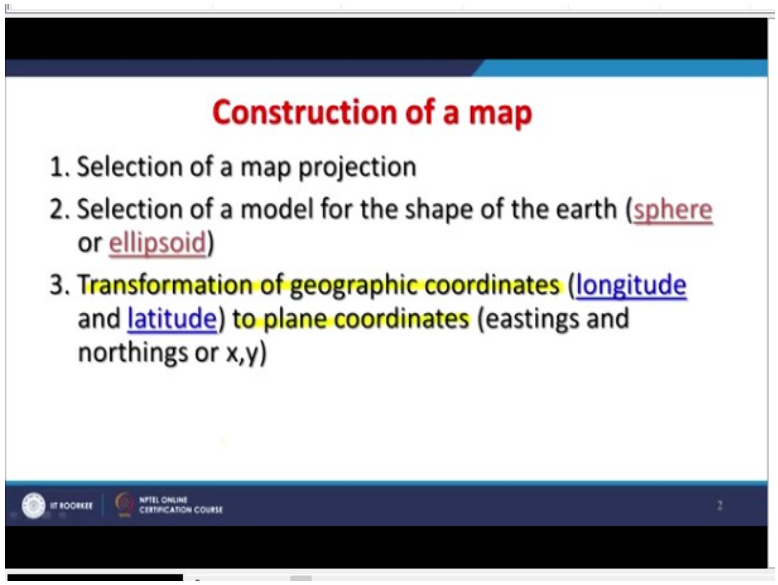

Each country will have its own, which we will discuss also what about the India. And then selection of a model for the shape of the earth that is the spheroids or ellipsoid that is also equally important for a map projection. Like for example in earlier survey of India toposheets, we used to have a polyconic projection. I will come to the conic projection or polyconic projection little later.

But just I am using the name polyconic projection and they used to have Everest spheroid for this representing the shape of the earth here. Now Everest spheroid is used mainly in Indian subcontinent. Everest spheroid is not used by any other one and this polyconic projection may not be used by any other one. So, if neighboring countries are using a different map projection, then the common boundaries between 2 countries, political boundaries may not match.

So, once the shape of a boundary is changed obviously then the length will change and problems will come. So, another issue is because GIS is very good on handling geographic coordinates in terms of DD or longitude, latitude. And the plane which we use for you know map, again it is a flat part so that means these curved lines have to be made straight lines on our maps or little curve and therefore the problems about accuracy of measurements will arise.

Second thing is about that the transformation of geographic coordinate that is latitude, longitude to plane coordinates. And in UTM projection, we use the easting and northing or x and y; generally, x and y. These easting and northings are in meters, not in DMS or DD. So, lot of changes or transformations are required from one shape to another, from one curved surface of the earth to the flat surface and therefore projections are very much required.

Another point which will come while making a map is the reduction of a scale because the real word is at one-to-one scale and on a map, I cannot represent the real world at one-to-one scale. So, I have to reduce the scale., I have to represent the abstract reality and therefore in GIS, we say that a topographic map is a model because it is representing abstract reality. So, reduction of a scale generally is required to map because the real earth is one-to-one scale and having you know, the spheroid body and 3D body whereas maps are 2D.

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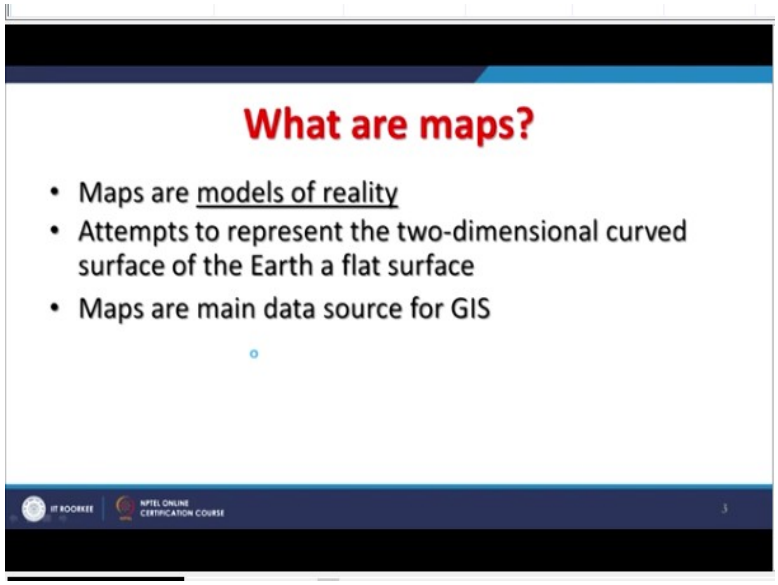

So, you know that maps are models of reality that they are also models and when creating map, what we try to represent the 3-dimensional curve surface of the earth as a flat and maps are main data source for GIS. Because in GIS, what we do mainly? We handle different layers; these layers are digital maps or in digital formats. Now generally what you can imagine here that you are having a wire mesh which is representing our globe.

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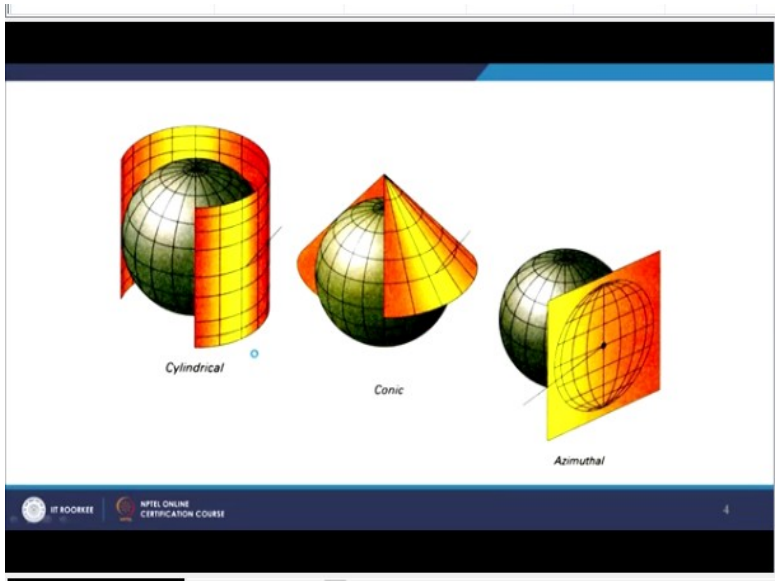

And these lines or these wires which you are having are the latitude or longitude. Of course, these are imaginary lines. On the ground, you do not see them except the 0-degree longitude which has been put on a building for Greenwich mean time or dividing the whole globe on eastern hemisphere and western hemisphere in London but that is the only reference which we are having.

Otherwise, these are imaginary lines, anyway. So, if you are having a wire mesh and if you keep a light source inside of that globe of wire mesh and if you put a photographic paper here and expose that photographic paper. And when you will make this sheet flat then you would see that impression of those latitude longitude will appear on this one. So, depending how we keep this paper or photographic paper over the globe.

And of course, this will depend where my country is located. So, if my country is located near equator then this way, I can get a true shape of my country and obviously consequently, I will have a true size of my country as well. But if my country is located near the poles or in higher latitudes then a cylindrical projection or keeping sheet which will be touching equator will not serve the purpose. So, again in order to represent my country in true shape and size I would change and I would create a rather than a cylinder, I may use a cone.

Suppose my country is located here then when I put the paper, it would represent near true or true shape and size. Similarly rather than making curve, if I just take it as a flat sheet and project on any on the location and the illumination source is inside again then I will get a

projection something like this. So, this projection word is coming basically from that concept of a wire mesh of globe and illumination source is inside.

And you are putting a photographic paper which I am exposing and bringing those impressions of latitude, longitude and depending where I am keeping, how I am keeping. Whether I am folding and if I am folding, how I am folding? So, if I make a cylinder of my paper which is touching this equator then these are called cylindrical projection. If I do it as in a form of cone as shown here in the middle figure then I say conic projection.

Now when I say India used to develop its toposheets in polyconic that means instead of one cone, multiple cones were imagined. And then there might be azimuthal projection which will touch just one part of the earth and rest is you are seeing like this. You know in many other disciplines also like in structural geology in earth sciences field, we also use projections which we call stereonets.

And these are for imagine; everything is imaging that it is in the southern hemisphere. So, that is also an azimuthal projection but south pole is in the center. So, this sheet is kept at the bottom if I want to do it but opposite to this in mineralogy again in field of earth sciences, we keep at the top. So, these structural geology concepts are also used in civil engineering as well.

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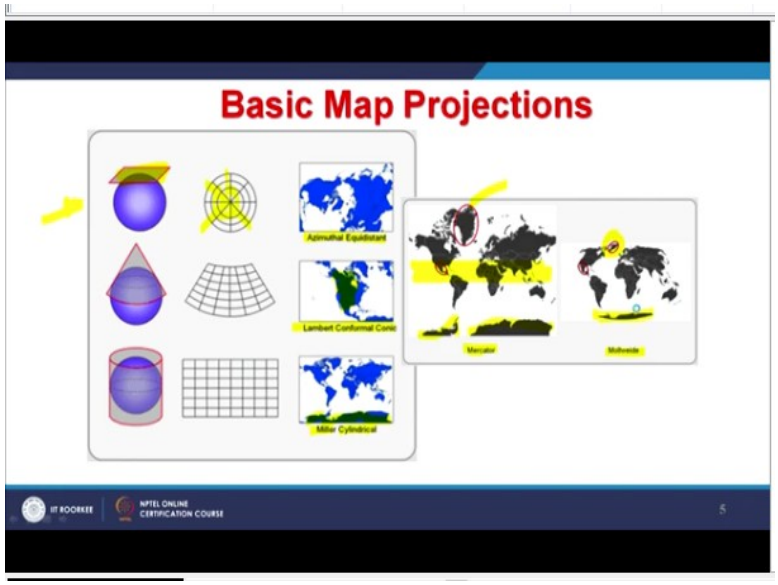

Now as I have mentioned already that there are 3 basic types of map projections that either azimuthal projection which you are seeing where latitude, longitude would appear something

like this that the latitude will appear as a rings and a longitude would be radiating from the center wherever I have kept. But if it is conic projection then again longitude would if it is of northern hemisphere then this is how it will be represented and so again these longitudes would be straight line here whereas my latitudes are going to be curved which is just opposite to azimuthal.

And when I am moving cylindrical then I am having very good representation in form of rectangles. So, my longitude and latitude would appear in straight lines. However, if we just compare the boundaries of these continents or countries where their distortions are coming. So, if I keep my photographic sheet at the north pole then thus countries which are close to north pole will appear in their true shape and consequently in true size, otherwise not.

But if a country is located near equator or something in the northern hemisphere like North America then it is very well represented in this conformal conic Lambert projection. So, it is a conic projection in broadly whereas this is azimuthal projection and this is cylindrical projection or somebody Miller who developed further so it is called Miller projection where latitude and longitude will appear straight.

Now again, it will depend where my country is located. And as you can see in the last example of cylindrical one, see what happens to the shape of Antarctica. We know that that this is not the true shape of Antarctica and Antarctica is a continent, nobody is basically living except scientist and therefore there is no dispute about the shape or no claim or no complaint that the shape of Antarctica is distorted in this map projection.

So, if we truly would like to represent Antarctica in its true shape and size then azimuthal projection like in the top which is shown, instead of keeping the sheet over the north pole if we keep on the south pole then we will get near true shape and size of Antarctica. So, different map projection will represent different countries in their different shapes and therefore almost each country has developed their own map projections in order to represent their country in its true shape and size.

Two examples are here given when we do the marketer projection, this is how we see. So, the countries which are near poles will have complete distortions but the countries which are near equator or something like that, they will have better representation. Similarly, here as you see

here that in this another projection, mollweide projection, see what happens to this green land part. It has got distorted shape and orientation also and when shape is distorted obviously the size would be an issue.

Similarly see what happens to this southern American part and that Mexico part also and what do you see that again it is distorted. So, basically map projection is a kind of trade-off. You get some benefits but some problems are also there. Similar problem is coming for the shape of Antarctica; it does not look Antarctica as we are used to or seeing a shape. But those who have developed, they have developed for their own country and for their own country, it is representing its true shape and obviously true size.

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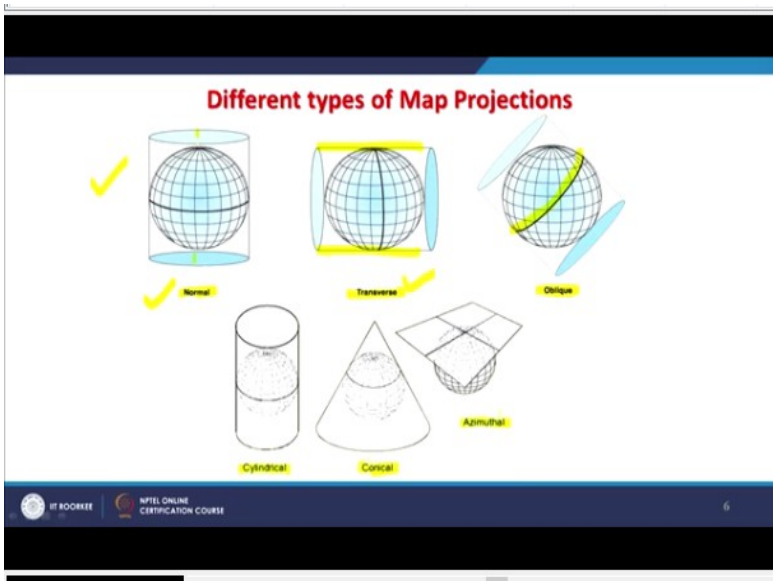

Now more complications can be added that you can keep where you want this flat sheet like on poles or on the transverse rather than on the poles in a normal projection or you can do it transferred putting this sheet or cylinder in a different way. If I take this example as a cylinder then this cylinder is put like this that in the center, you are having north and south. Here you do not have north and south; north and south have gone on the sides.

So, it would be a transverse projection. So, this is called normal projection, this is transverse projection. Now it is again a cylinder; so, inside that cylinder that the ball or this we can keep as an obliquely like as shown here so it becomes oblique. So, this is the line which is shown is where every place the cylinder will touch the earth but rest of the places, it would touch except on the polar regions, otherwise it will not touch.

So, when we project it would be, so complications are will be there or combinations of these. Obviously, we do not have to do nowadays physically all this. There are mathematical models and conversions are there. That means we can convert from one map projection to another. However, changing from one map projection to another, for example from our polyconic projection of survey of India, if I change to UTM projection there might be some problems while changing.

That means there might be introduction of few errors. So, we have to be very-2 careful because these errors will basically distort the length and area and shape also; maybe a district boundary or maybe state boundary. So, there might be some issues also. Overall country boundary will also get distorted. So, cylindrical projections, conical projection, azimuthal projection depending where the country is located on the globe.

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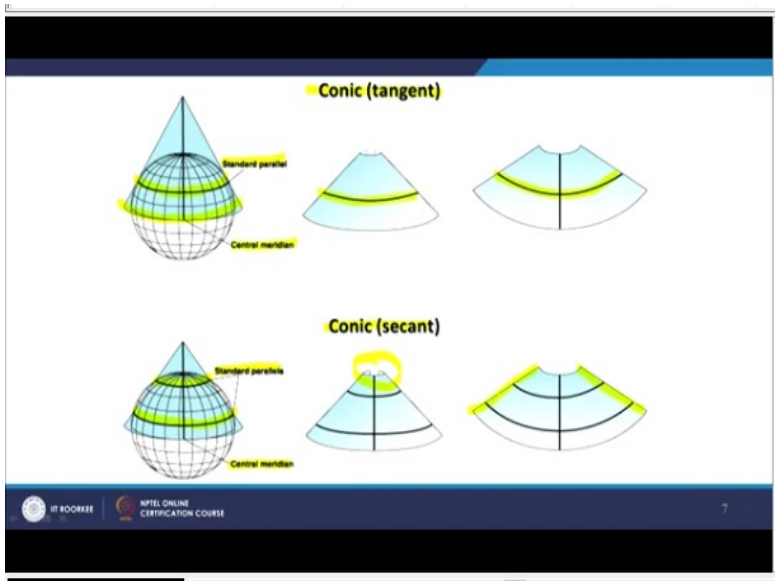

Now when we go for this conic tangent then this is we call as a standard parallel which throughout that cone, it touches the earth so that becomes our standard parallel. And central meridian is that which touches the bottom of this cone and it is currently coinciding with the equator so that becomes my central meridian and this is how this is standard parallel.

And then these longitudes are also shown here likewise. If it is a conic secant then this is how instead of coming to up to equator, it is going down so my central meridian is going to be like this and standard parallel has gone up and there might be even 2 standard parallels. So, like in survey of India polyconic projections, we had 2 standard parallels. And similarly, when we

take out the globe or wire mesh out of this. This is still in cone shape but when we make further flat, it would look something like this.

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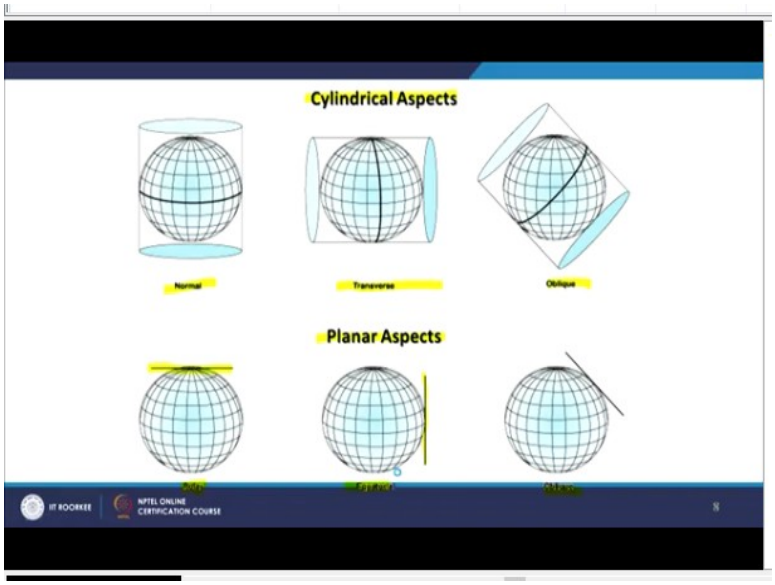

Similarly cylindrical when we go for aspects normal, transverse and oblique. When we go for planar aspects rather than having a cylinder of the paper, we go for the flat paper then what we are having the polar projections as I give the example of structural geology or mineralogy where we keep or other projections which you are seeing oblique projections or transverse projections and other things are there.

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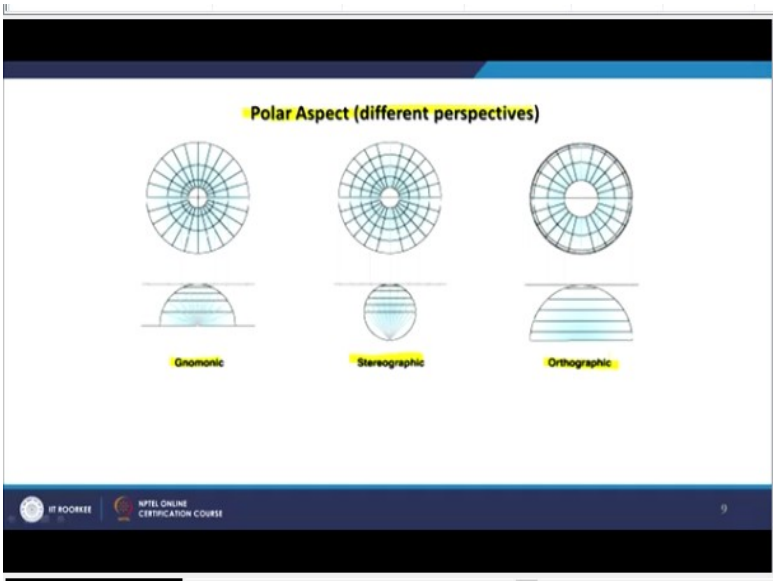

So, if we go for further details depending on this in the polar aspects that different perspectives are there. So, a gnomonic, stereographic; these are the projections which are used. A stereonets, we also call is stereographic projection about structural geology and then

orthographic is also done. Orthographic corrections on satellite images are also performed. So, this is based on nothing but the projection basically.

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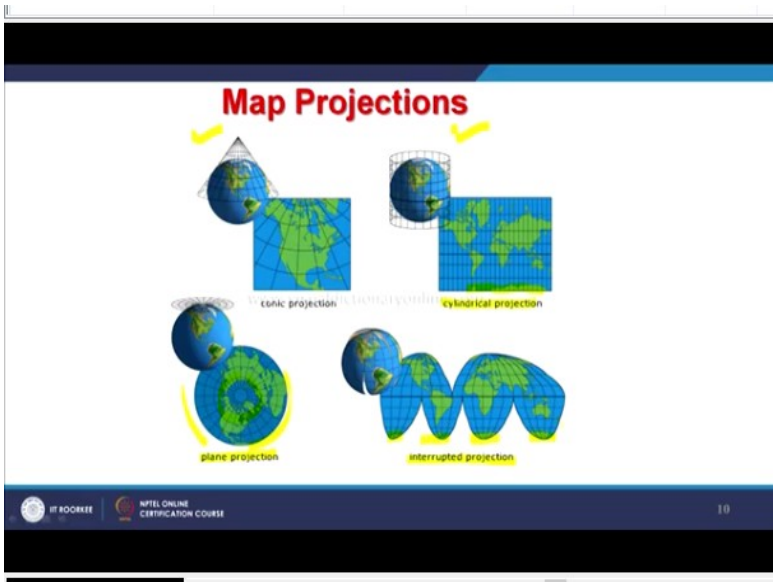

Now with the boundaries of the countries are also depicted here that if I am having a conic projection like this or cylindrical projection then US; north America, Canada is appearing something like this but when I having a cylindrical projection, I am having a very much this Antarctica distorted means polar regions are distorted but in between mid-latitude countries, both on northern side and southern side of your equator are quite represented correctly.

When I am having plane projections again wherever the sheet is kept or projected then like this is our northern hemisphere; things are very well represented but what happens near the equator or in the southern hemisphere, you do not have anything to see there. And this is interrupted projections or polyconic kind of projections where you handle like a peeling of an orange and this is what you can see here.

So, when you peel off an orange very carefully using these designs or lines then when you open it, it might look something like this. So, these are also interrupted projections. More or less, all countries would be represented correctly but see what happens to your Antarctica. It is now in 4 parts which is not correct way of representing. So that is why I said earlier that there is always a trade-off in map projection. You gain something but at the same time, you lose something,

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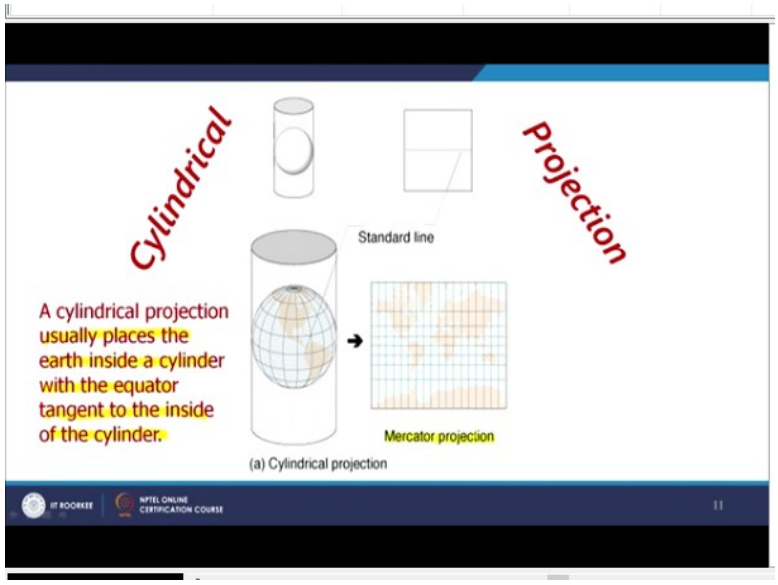

Again, cylindrical projection in which you are having places; usually places earth inside a cylinder with the equator tangent to the inside of the cylinder and you get a marketer projection. So, there is a universal transverse marketer projection; UTM, very popular and this is how that is done like this. So, also that is called equal area projection.

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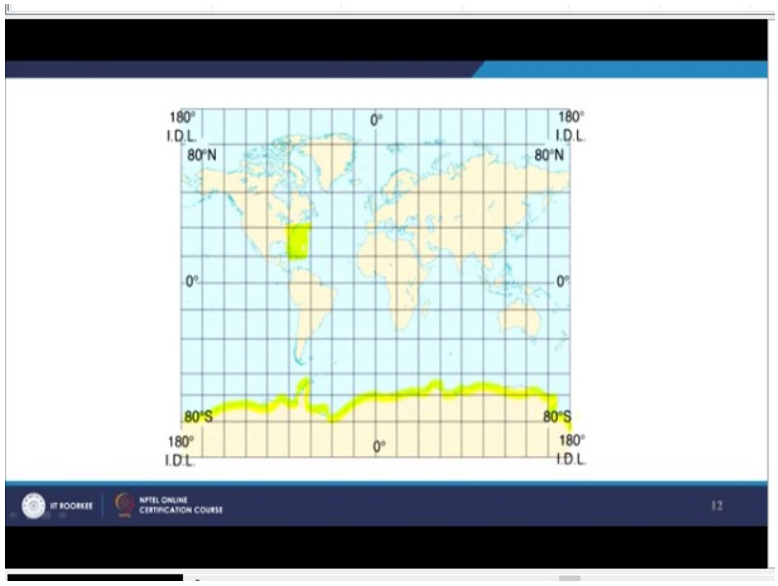

So, if I take that kind of scenario, again the middle latitude countries would be represented nicely without any problem. And why it is saying because each cell here is representing the same area of the earth so it is also called equal area. However, see the Antarctica; what happens to the Antarctica? The entire shape of Antarctica has got completely distorted. It looks much-2 larger than over all of the countries which you are seeing, which is not true.

So, in a particular projection, thing may be very bad for others, that is why there are so many projections are there and there is virtually no universal map projection, not even UTM is also not universal truly.

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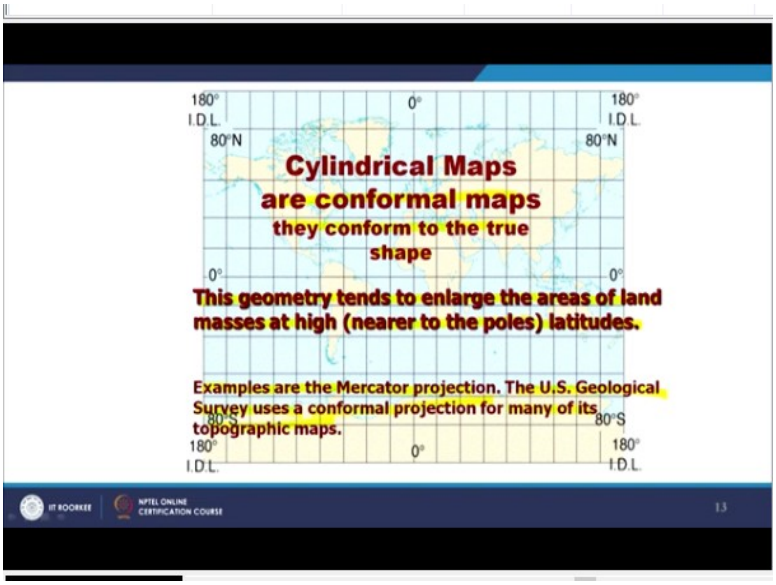

So, cylindrical maps are conformal maps and they form to the true shape, only to this geometry tend to enlarge the area of land masses at high, the near at the poles or latitudes as you are seeing. Examples are marketer projection. The US geological survey uses a conformal projection for many of its topographic maps.

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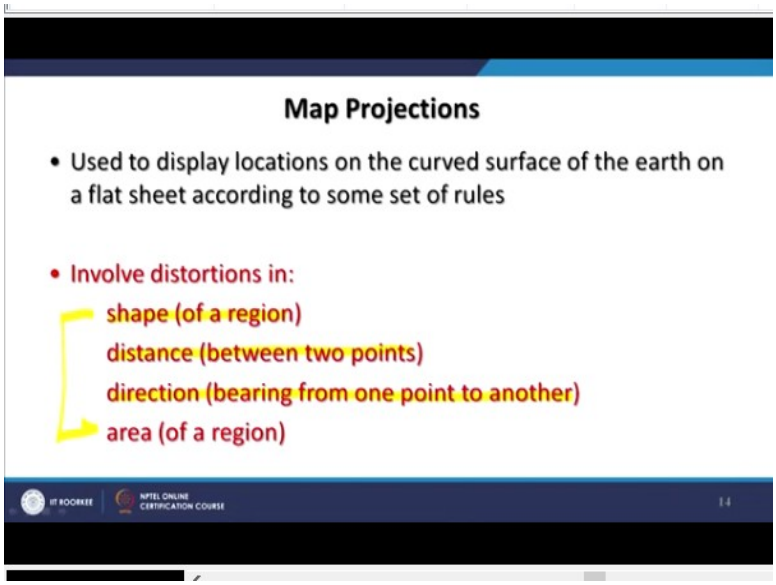

Now as you know that the curve surface, 3D surface has to be represented in a flat sheet. So, the projection has to be chosen. Now when you do it, what the problems which we are going to encounter is the shape of a region or a country. Political boundary may get distorted, the

distance because shape is changing so the distances or perimeter will change and the directions will also change. I showed one example of Greenland in one projection, it was a different direction. Another one, it has got completely different direction

And the area when the shape is changing the area of a boundary will also change. And these are the distortions in map projection can introduce. Now while converting from one map projection to another, these distortions I try to keep at the minimum but still there might be errors because no projection transformations are completely transparent.

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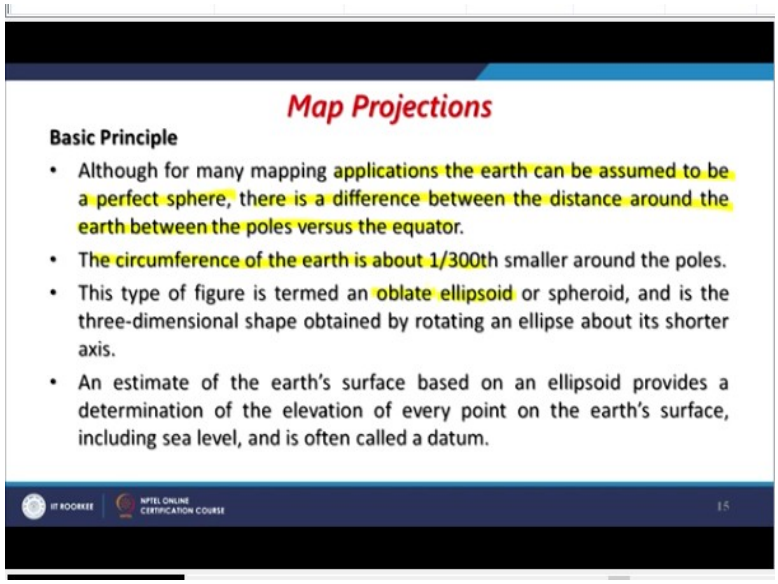

So, basic principles of these map projections that mapping applications because this is what we are doing in GIS that applications of the earth can be assumed to be a perfect sphere and there is a difference between a distance around the earth between the poles versus equator. Because again the earth is not perfect spheroid and that added lot of complications that the circumferences of the earth is about 1/300 is smaller around the poles.

And this type of figure is termed an oblate ellipsoid or a spheroid, not perfect spheroid. And the 3-dimensional shape obtained by rotating an ellipse about its shorter axis. So, if we move that one then we will get this oblate ellipsoid and that is why it is also called ellipsoid. It is not the circle which we will move over this north-south axis. And an estimate of the earth surface based on an ellipsoid provides the determination of the elevation of every point on the earth surface including sea level that is often called the datum.

So in GIS, we also use datum and like in GPS or GNSS, the word geodetic spheroid is used whereas I gave the example so these are also called the datum as well.

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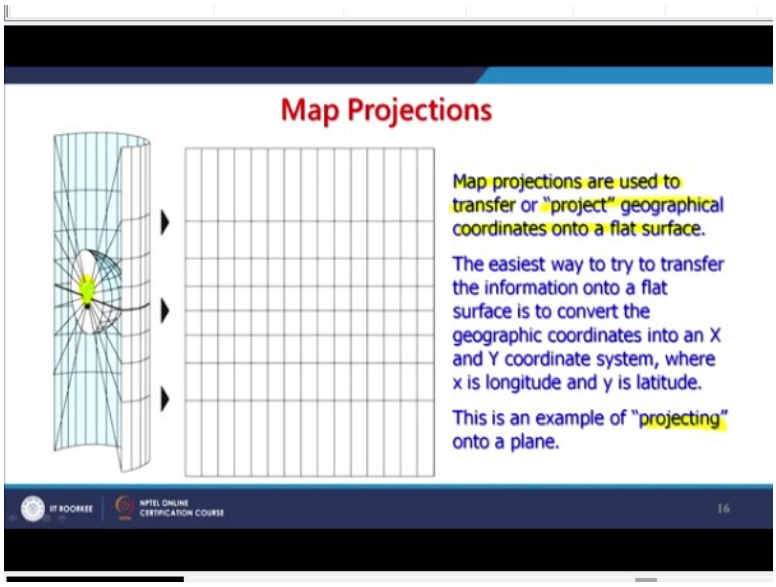

Now these map projections I was giving you earlier that the source of illumination or light source is kept in the center inside the wire mesh and when you project and make it flat, this is how it will look so depending how the paper has been folded and where it has been kept. So, map projections are used to transfer or project geographical area coordinates into a flat surface.

And easiest way to try to transfer the information onto a flat surface is to convert geographic coordinates into X, Y coordinate system. And this is what we do. And most of the time when we handle the data, we display in geographic coordinates, at that time it is not projected. But whenever you are going for some calculations or estimations of distance, perimeter or area then it is better to project them on to a plane.

And then do those measurements, you would get the correct one. For India if we project in the UTM projection, we get very accurate measurements using that projection. So, initially you can keep your maps in X, Y coordinates or in DD but whenever you go for some measurements, you can convert temporarily to a map projection UTM, do the measurements and then come back for other analysis.

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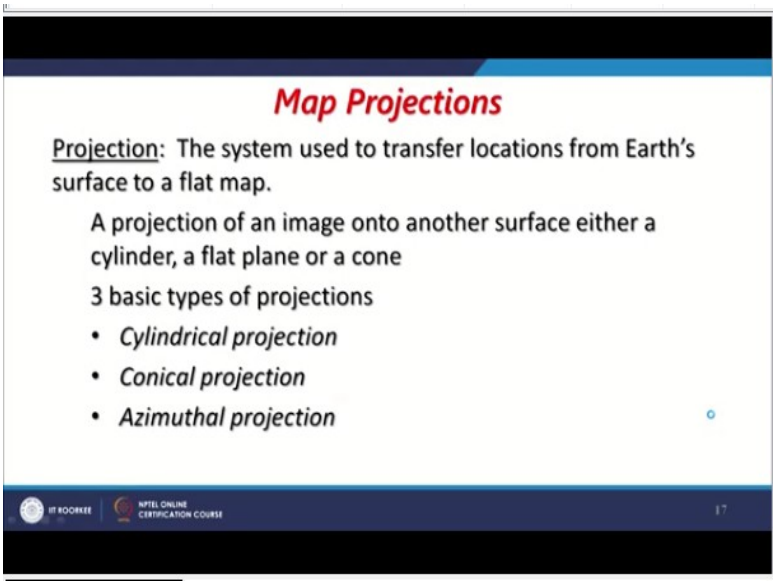

So, projection systems; basically, the system or computer or GIS used to transfer locations from earth surface to a flat map and projection of an image or satellite image onto another surface, either a cylinder or a flat plane or a cone. It depends where it is located and the basic types of projections, I have already discussed that one is cylindrical, conical, azimuthal; these are the 3 basic types are.

Now equal area projection as I have said UTM is also considered under that category where it correctly represents the areas, the sizes of the sphere on the map. That means if I project my data into UTM and do the area measurements, I am going to have better accurate results. For example, Lambert cylindrical equal area projection which is specifically designed for this equal area concept is there.

Then equidistance where the distance is correctly represented; equidistance projections. Example is a plate carry projection which we do not use in India or survey of India do not use these projections. And then the conformal projection where represents the angles and shapes correctly at infinitely small locations so there also. Mercator projections, again this UTM projection is an equal area mercator position. So, it is a conformal equal area projection, it is a mix of these 3 types.

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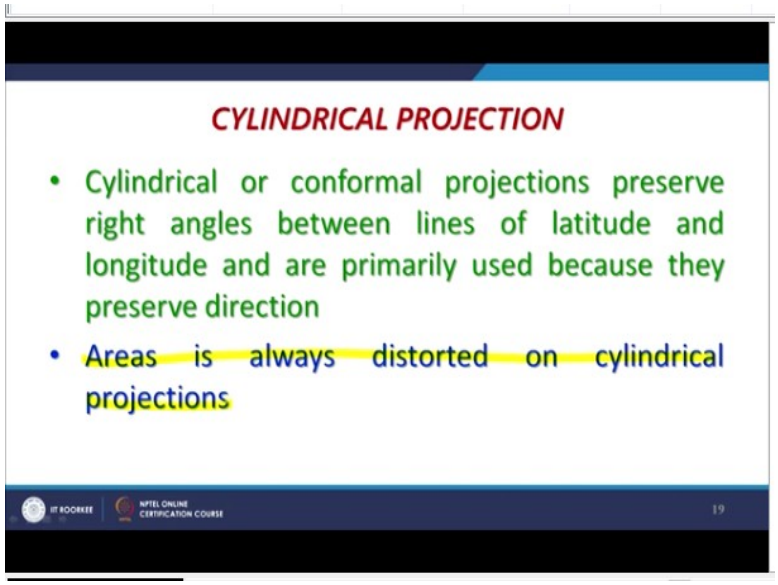

Now in cylindrical or conformal projection, basically they preserve the right angles between lines of latitude and longitude and are primarily used because they preserve direction. So, for different purposes, different projection systems can be employed. And area is always distorted on cylindrical projections. So, one has to keep this because you know that these latitudes, longitudes are curved lines; imaginary lines on the surface of the globe. And if you make them flat obviously, they are going to bring distortions in this.

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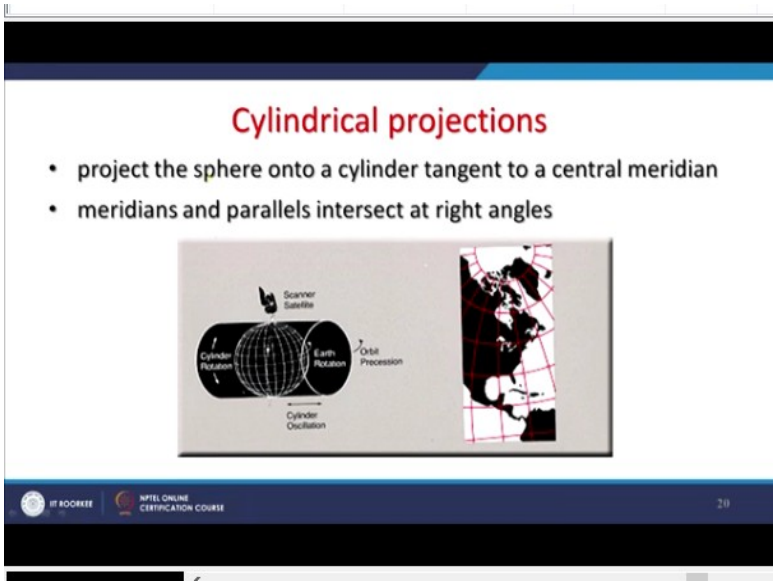

So, cylindrical projections; here you would have a problem and also when data from satellites are acquired, they too suffer from this. So, many times we try to remove those distortions using your geo referencing techniques but map projection has to be taken completely differently. So, project the sphere onto the cylinder tangent to a central meridian, one choice

then meridian and parallels intersect at right angles. So, when we go for cylindrical projections, these conditions are there.

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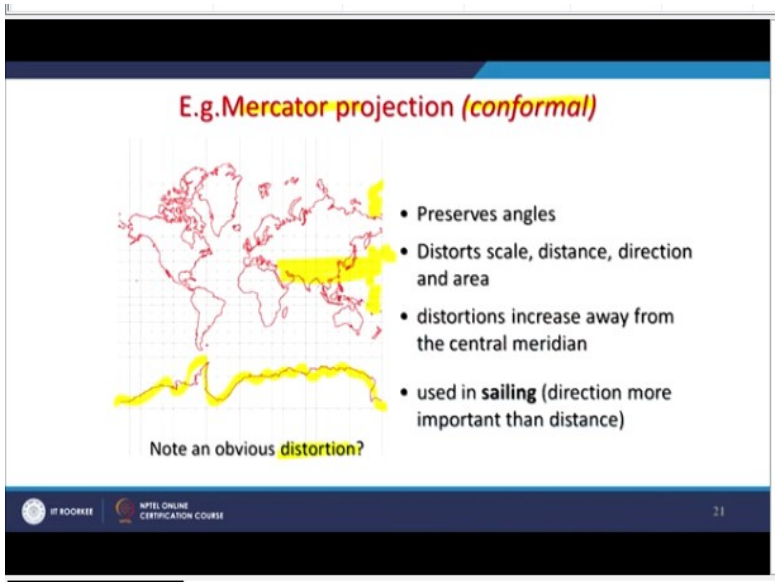

If we go for mercator projection and that is conformal, this is how globe would be or the boundary of the countries would be represented. The big problem which you see over the Antarctica or the northern pole countries but the areas in middle latitudes around the equator would be well as you can see that for the same area of the earth because it is conformal.

So, for the same area of the earth; here at this range of latitude, we are having square whereas in the near equator we are having rectangles like here. And if we go little higher latitudes, we are again finding rectangles having a different orientation. So, thus you know, same area is represented as a very large area and this is what, it is bringing the distortions.

But it is achieving very good results for mid latitude countries. Mercator projection like for countries like India, it is quite good in that sense which preserves the angle, this mercator conformal projection. Of course, it distorts scale, distance and direction of areas. Distortions increases away from the central meridian and used in ceiling, when in the ships or for the direction more important than distance because they have to keep the direction intact.

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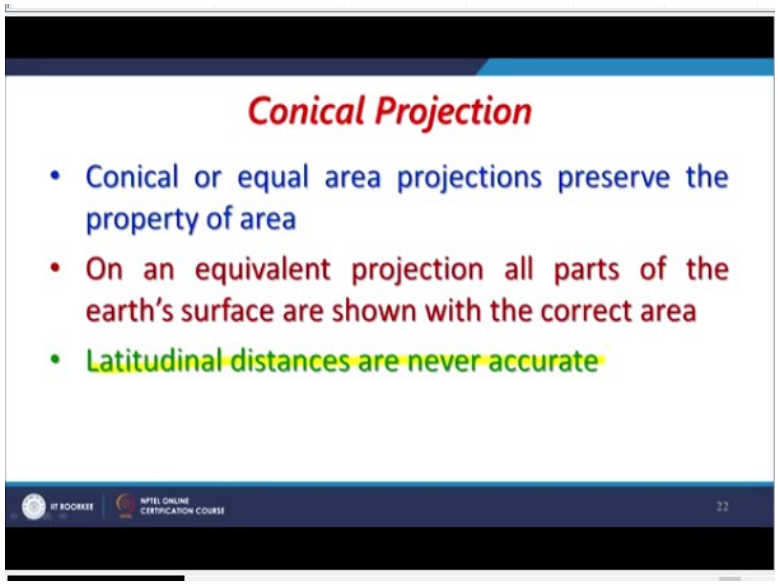

So, in conical projection or equal area projections preserves the property of the area and on the equivalent projection, all parts of the earth's surface are shown with correct area. So, area is preserved here. In the previous example, the direction is preserved and latitudinal distances are never accurate. So, again if somebody would like to do measurements.

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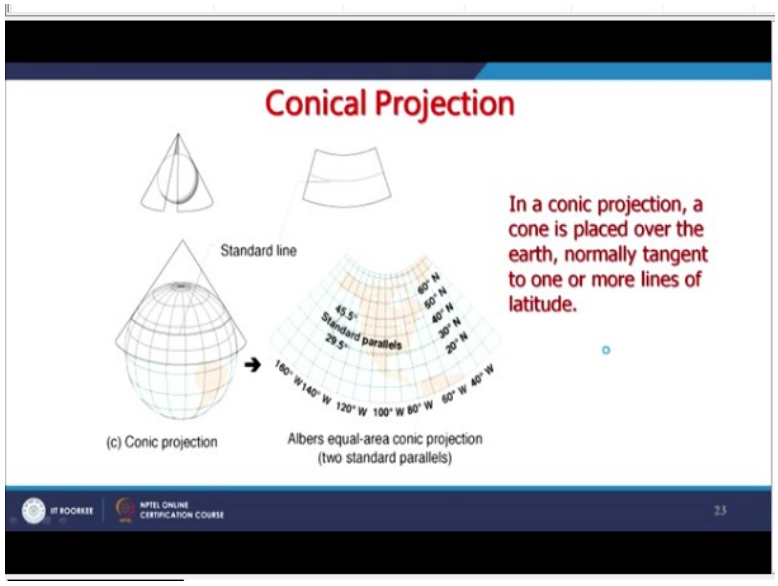

So, each projection is having its own advantages and disadvantage that is why I have repeatedly said it is a trade-off. Trade-off from one has transformation to another but where you are located or for which area you are working, that is important.

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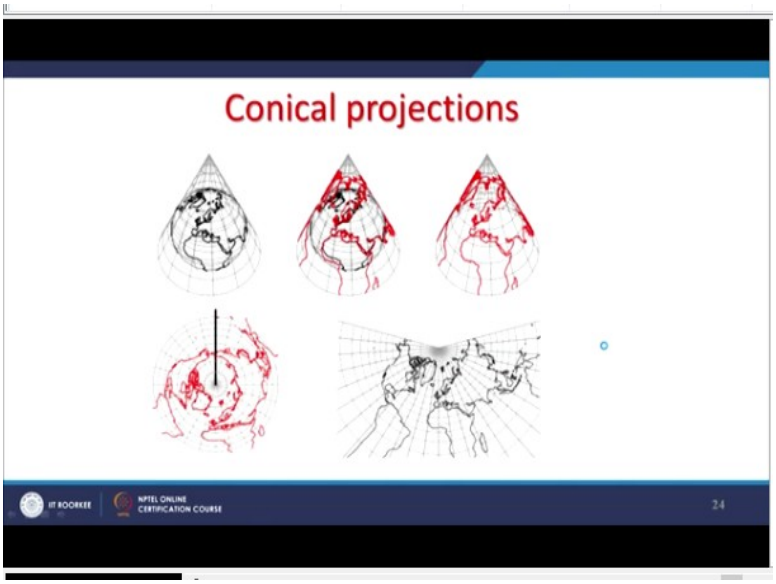

So, by that, you can really control a lot of things. For conical projections, similar problems you would encounter.

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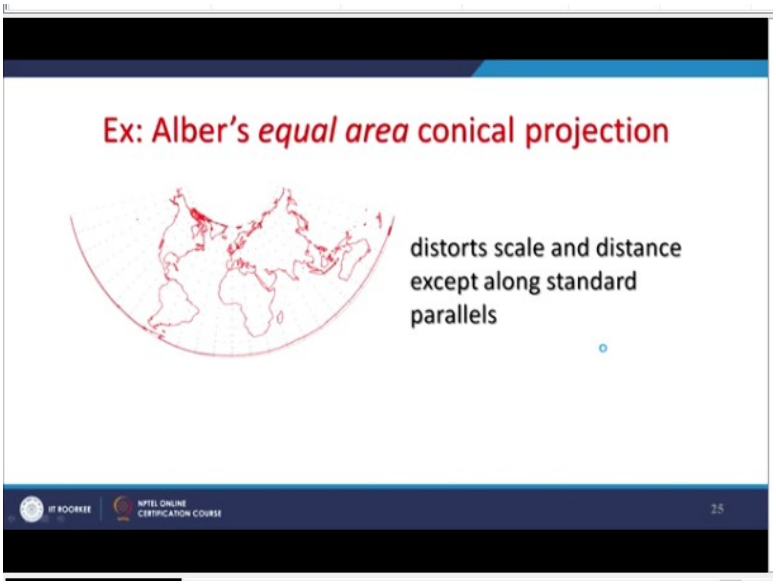

For this Alber's equal area because when we go for the demonstration of map projection on the software, I would show that how the softwares developers have developed all these transformations functions for one projection to another. Initially many-2 years back, group of scientists developed first this transformation functions in the USGS. Later on, they coded in the FORTRAN computer language. And now these have been coded in other languages too.

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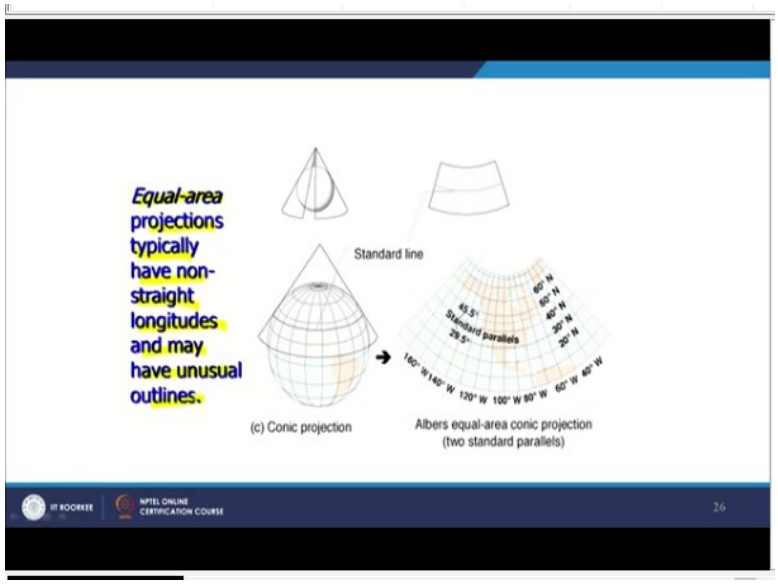

Like for example here, equal area projections typically have non straight longitudes and may have unusual outlines. So, some distortions at some place might be there. Whereas in azimuthal projection, only preserves the correct distance relationship along few lines on the map because it is just touching at one point.

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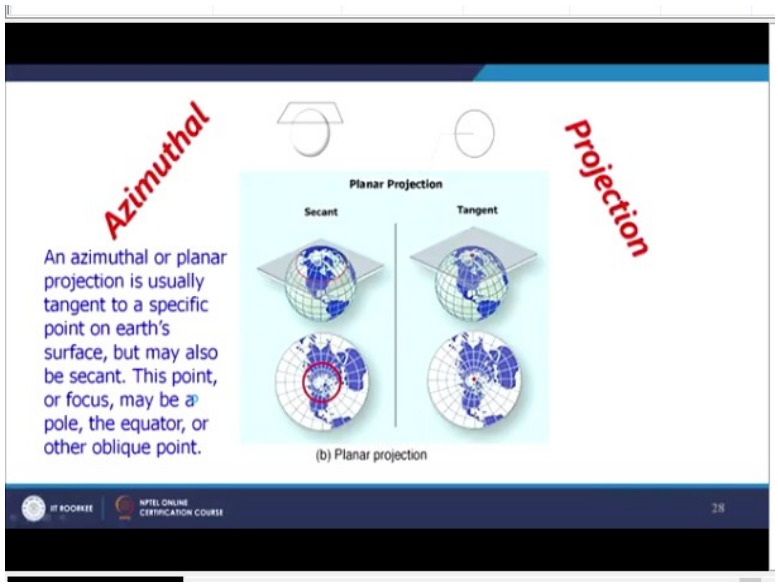

So only on the few lines on the map, it is good but otherwise it is bad. So, where that sheet is imagined? I you are having a second touch; it would be like this. If you are having a tangent touch or tangent connection, it would be like.

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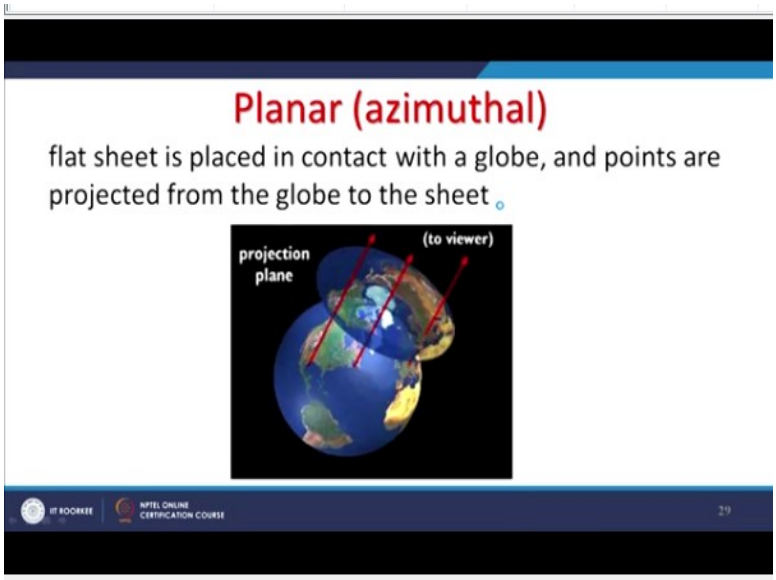

This whereas planar or azimuthal that is flat sheet is placed in the contact with the globe and points are projected from globe to the sheet and likewise you can have a projection like this one.

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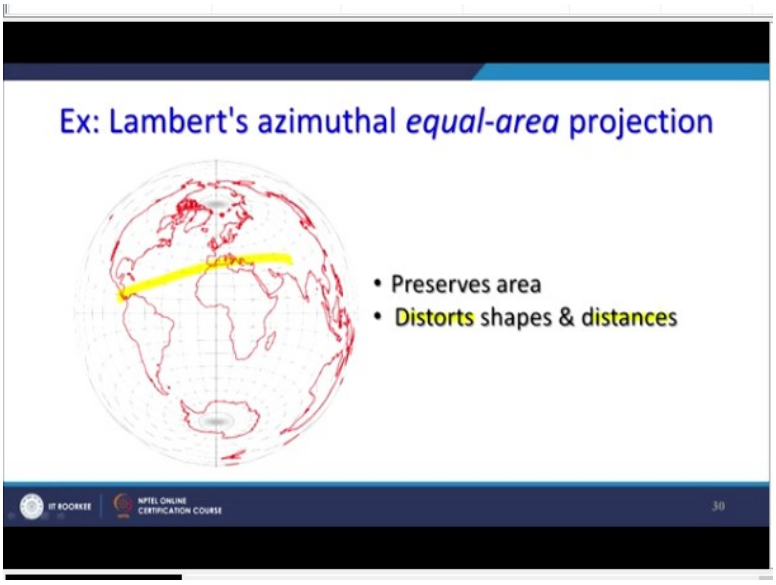

Similarly in Lambert azimuth equal area projection which preserves the area but distorts shapes and distances. So, what you see in a google earth, this map projection is there but when you zoom it then these distortions which are coming because of curvature of the earth will not be there and therefore if you do the distance measurements, you are not going to encounter big problems.

But if I do distance measurement on while projecting in this say between here to India, I may get distortions in my distances. So, depending on the scale; scale is also very much important.

If I am working on a small area having large scale maps then the curvature of the earth will not play much role and therefore these things can made.

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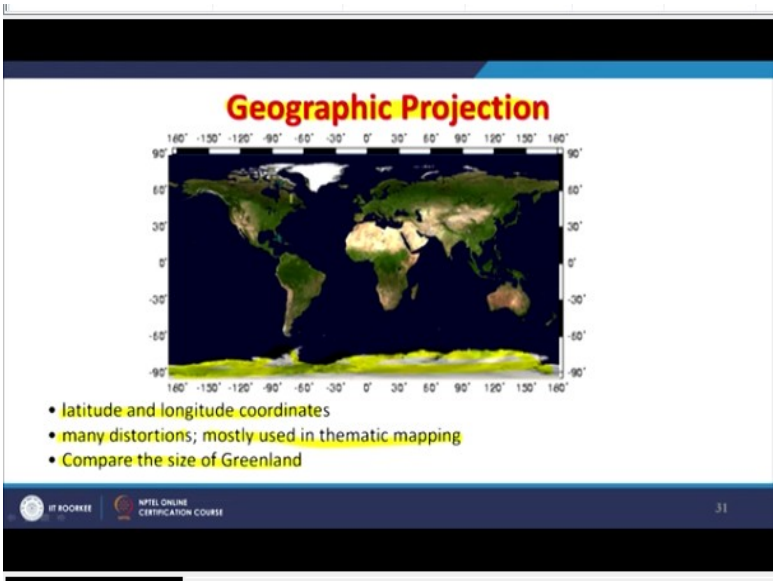

This is what the geographic projections so generally by default in GIS, we keep geographic projection where we keep the things in latitude, longitude coordinates. And though it distorts because as I have said no projection is truly inversal or perfect. Every projection is having problem; one type or another. Either shape is correct, distances are bad or area is bad or something like that.

Here again in this particular geographic projection or no projection, it is also called no projection in some literature. So, if no projection that means geographic projection, again the polar regions are completely distorted but the areas which are near equators or countries which are near equators are nicely represented. So, many distortions are there. Mostly used in thematic mapping, this is what most common one in GIS.

And what happens to the size of Antarctica or Greenland, it has completely changed which is not true as if we can check in other polar projections. Now people have also developed some projection which are called compromise projections.

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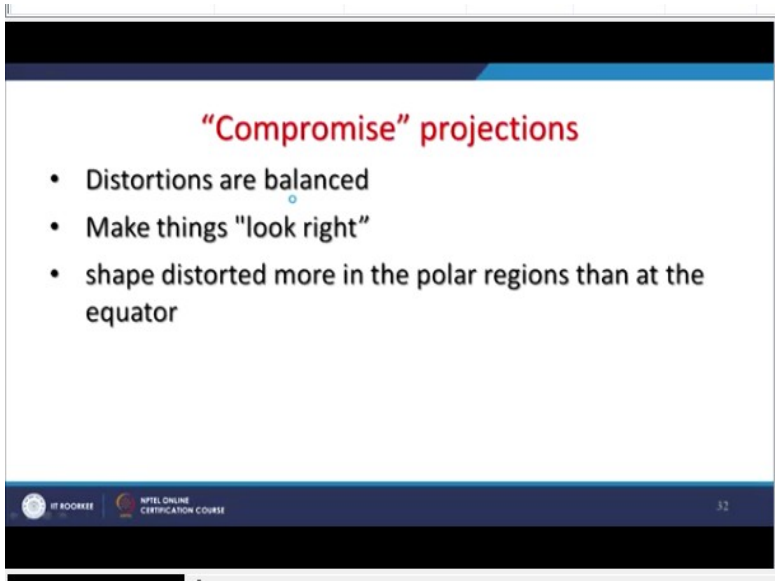

So, they try to balance the distortions and also make things righter or look right also and shape distorted more in the polar regions than at the equator.

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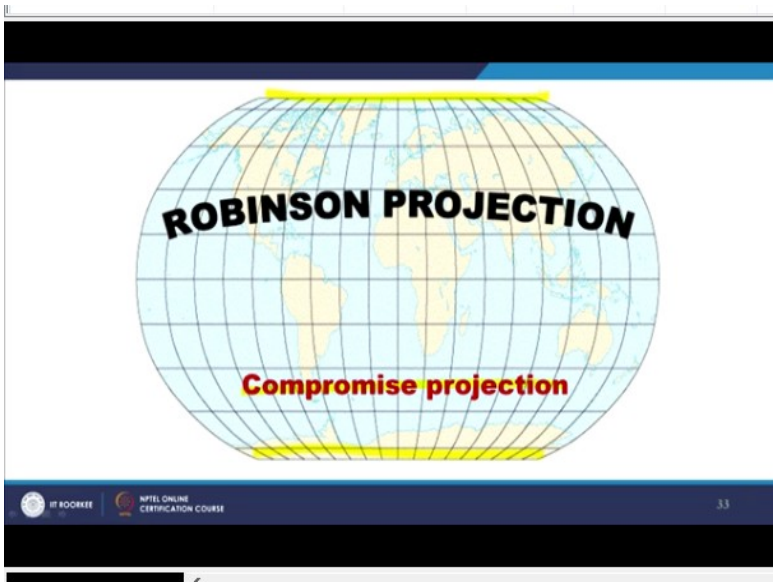

So, this is the compromise projection which is called the Robinson projection, though at the polar regions you are having very bad distortions but in the mid regions, it is quite good.

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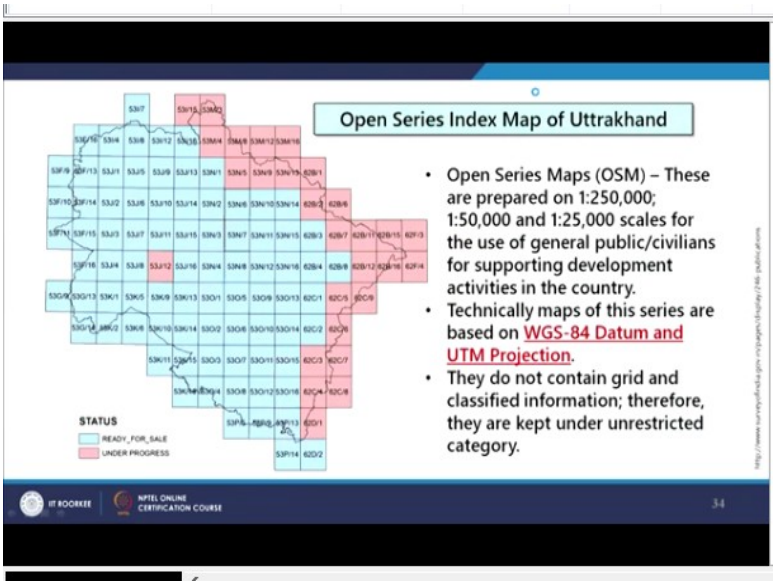

So, again there are advantage and disadvantages mean trade off. Now we are coming almost end of this discussion about map projection. So, before I close, I would like to mention about the latest or new series of survey of India because we will be handling these maps for buildup of our GIS database. So, a brief discussion I thought would be most appropriate.

So, what we are having that now this is the index map of Uttarakhand but open series topographic maps, they are using this datum as a word geodetic spheroid 84. This is the same spheroid is also used in default by our navigation systems like GPS or IRNSS or BeiDou or Galileo or Glonass. So, it is conformal or it is matches with those standard so therefore there will not be any conversion required if I collect data from GPS and plot over open series maps.

Earlier when we used to collect the field data using GPS and when we used to plot on toposheet, we used to get lot of location errors. But now if I do it on these open series maps then that problem will not be there because one thing that they are following the same datum as these GNSS systems are following. Another one the UTM projection. So, the area issue will not come because we are not located on the poles, we are just above the equator.

So, in that way it is very good. So, open series, these are basically prepared at different scales 250000, 50000 and 25000. And these are not restricted as well. In the earlier system, we used to have lot of restricted toposheets and difficulties to do that. And as you can see here that for entire Uttarakhand, it is showing also status and all blue one is ready for users whereas on the border areas or in the one in the center, there is some under progress situation is there.

And these toposheets if you buy open series, they do not contain any grid that is latitude, longitude grid. And they do not either contain classified information. Therefore, they are kept under unrestricted category. So, these are available to anyone who would require for their uses. Maybe for development of an area or maybe for GIS purposes or maybe for some project or construction or any other thing.

Because of no restriction and now using GPS or GNSS, you can use the locations which will plot very accurately on this one. So, this brings to end of this discussion on map projection. Again, same request, please try to take a map of the world or political boundaries of the world in your software and try to change from one projection to another. When we will have demo, of course we will be seeing all those details as well. So, thank you very much for time being.