Higher Surveying
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Module - 02
Coordinate System and Reference Frame
Lecture – 04
Projected coordinate system

Hello everyone. Welcome back in the course of Higher Surveying. Well we are in the module 2 and this is our third lecture of module 2. So, this lecture is projected coordinate system.

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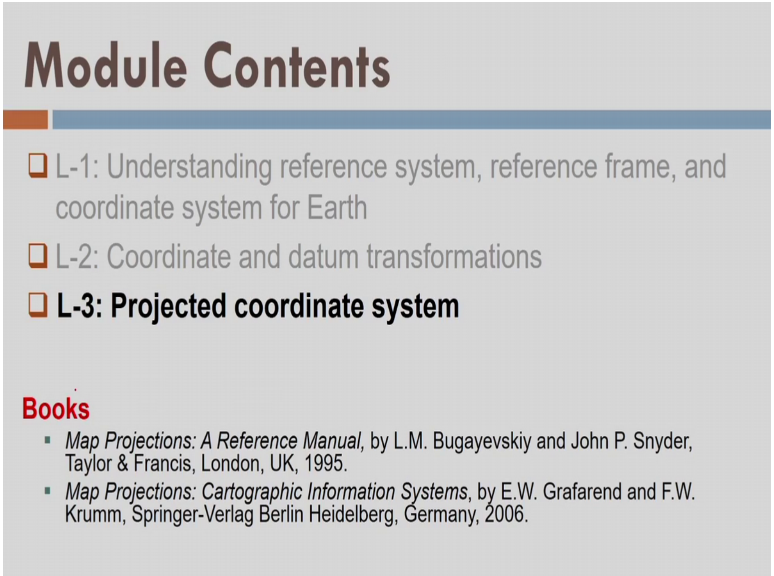

In the previous two lecture, we learned about how to establish a reference frame, how to establish a reference system, how to conceptualize a reference system, how to establish a reference frame that is a realization of a reference system and later, we decided that how can we use the coordinate system or different type of coordinate system to locate one point or a multiple points.

Well this was a good background for us to understand different kind of a coordinate systems and reference frame for the earth. Remember that, earth requires a different set of coordinate and reference frame, why because it is no more of plane surface. It is a curvilinear planet, ok. In the lecture 2, we realize that how to develop a transformation between the local reference frame to geocentric frame or maybe geodetic frame, later you also realize that how to convert a geodetic frame to geocentric frame using datum transformation and so on.

So, there we define two terms; coordinate transformation and reference frame transformation. Reference frame transformation where we change the definition of a reference frame from one to another and that we also called datum transformation. In case of coordinate transformation, remember we are to we are not going to change the reference frame or the ellipsoidal surface, ok. So, that was a understanding we have already developed.

Now, in this lecture of this module, what we are doing here? It is slightly spatial. Surprisingly, we are again going to the projected coordinate system where we are going to project the curvilinear surface of the earth on a plane surface. Remember in the first lecture, we have criticized this approach in the first module itself. Then, again we are going back what could be a reason? Yes, there are some valid reason for that and this time we are going to do it for a very large area and not for a small area.

Remember for a 10 kilometer length on the surface of earth, it can be understood as a flat line also or a flat plane also because the distance or the difference of the distance between the 10 kilometer curvilinear length on surface of a earth and the 10 kilometer distance along the line of collimation, only have a difference of the millimeter. And for that reason, we assumed in a plane survey that we can use the projected coordinate system or we can assume the flat plane of my reference frame for planimetric coordinate system. Well so, that was our preparation, but later on again we are going to do the same thing; however, we are this time doing for a very large area, for a maybe some 100 kilometers or so, ok. But before that we should understand, what is the requirement of doing that? So, let us go into this lecture.

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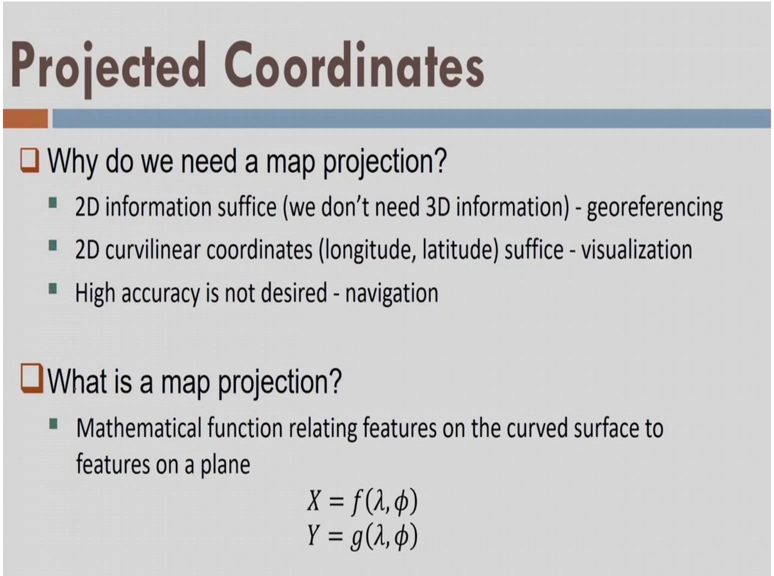

First of all, sometimes the 2-dimensional information, it is sufficient for me ok. I do not need the 3 D information and the first example is georeferencing. Georeferencing is a process of assigning the coordinates to a image; satellite image or camera image or a aerial image, here, I would like to give you a brief introduction about that, you might have done it or if you have not done it, no problem.

Just understand it is a example of an coordinate transformation, where I am assigning the coordinates of a map to the image. So, what will I do? I will select the common points between the image and the map; that means, for a given area, I have already image with me, it could be satellite image, it could be aerial image or it could be a terrestrial image; that means, it is an acquired image from some camera, ok.

Now, I will identify some features on that and I will identify the same features on the map. From the map, I will take some coordinates of those features and I will assign those coordinates of the map to the same features in the image. Then, I will rotate that image into the map coordinate system. Well, that is a very simple process, but here if you look at, I just want to do a 2 dimensional coordinate transformation or where I am using only x and y coordinate of the map as well as 2 dimensional coordinate of the image that is pixel coordinates row and column. So, it is kind of 2 dimensional coordinate transformation going on.

Then, that is a first requirement for this particular case of georeferencing. We understood that, so we do not need the third dimension because after doing the georeferencing of map, I am to going to classify my map; that means, I am going to identify which area is let us say forest which area is a agriculture, which area is a sand, which area is a river and so on. So, for that purpose, I do not need the 3 third dimension or the third information on the map, fine. The second is 2D curvilinear coordinates that is longitude and latitude, sometimes they itself suffice the purpose or they are sufficient.

For example, another good example is visualization. In case of a visualization, it is very important to understand latitude and longitude why because, if you remember in case of a geocentric coordinate system when I said before also, it is good to work mathematically or computationally. But when you just imagine that, if I give you some kind of 3 D information let us take capital X, capital Y, capital Z of some point on the earth that could be some 6 lakhs something, some figure and the second figure and third figure.

So, there is a complete tuple x, y and x and I ask you, can you please identify the position where this point is indicating on the surface of a earth, extremely difficult a rather it is impossible to comment, ok. So, but if you look at the longitude and latitude if I say, the latitude of a place is almost around 21 degree and longitude of the place is 91 degree or 91.5 degree, you can say yes this place is somewhere around Guwahati, why, how could we imagine this thing?

Because you know that there is some 0 degree longitude if you take a kind of curve here or kind of angle here which is equal to longitude, 91 degrees and then, you will take from this horizontal equatorial plane or I can say not horizontal, but equatorial plane if you take this angle, vertical angle along the any latitude line or along the meridian line and if you measure around 21 degrees, if we imagine, it is very easy for utilization that you are somewhere near to the Guwahati.

But for that purpose, you do not need the third dimension that is a height and if I further add it, let us say that wherever place I am indicating by 91.5 degree and 21.5 degree, this kind of longitude and latitude if I say the place itself has a height of 55 meter and ellipsoidal height or maybe orthometric. Then, you come to know yes with respect to some ellipsoid, this place is 55 meter high and what if I say let us say 100 meter high, so place identification is not going to matter a lot, once I give you 2 dimensional coordinate; that means, the third information is not going to make any change in the place identification, well.

It will certainly add some information which is sometimes is very important, but as far as identification is concerned, we do not need the third dimension. Thirdly, I have high accuracy requirement for my some of the work. Now, at sometimes, I do not need it. Just take an example, today evening you want to go with your friends for some recreation. So, as a result you want to go to some restaurant to celebrate some party, ok. So, what will you do you know that there is a restaurant and it is which is very famous in your study.

But you do not know how to reach there. So, what will you do you will take your smart phone or a mobile phone like this and then, in your mapping services, you will apply a position or you will use the two positions one is your own position your at your home and second one is the destination that is restaurant, ok. You give the name and your mapping map service will give you that is a shortest route along the map and then you will start using a GPS.

So, GPS will tell you your position when you are moving, ok. Now, let us see your about reach to that restaurant fine and that restaurant is on the left hand side where you already moving because we have a from left hand system here in India where you are moving on the left hand side of the road. So, around 3 to 5 meter or 10 meter, you will come to know yes you are about to reach to a restaurant. So, do we need at this stage a kind of centimeter level accuracy to reach there absolutely no, you are very comfortable with 3 to 5 meter accuracy also.

Because your purpose is to reach the restaurant once you are around the restaurant, you will just look at this restaurant and you will enter into that. So, you need identification of the place in this case also; that means, what are the surroundings. So, what will you do? You looked at the surrounding of the restaurant and you try to figure out where the restaurant is when you are very closed to that let us say within 5 meter. So, I think within 5 meters, you can directly see the restaurant also very easily

So, what information you need here? If the restaurant is on the left hand side of the road, it should be shown on the left hand side of the road on your map or if it is on the right hand side, it should be shown on the right hand side of the map. And that is it and if I assume that if there is a 2 line road which is 3.5 meter each length which is generally at the dimension. So, within 2 to 3 meter or 4 meter accuracy, it is sufficient for you.

So, with this idea we know that at times, we do not need high accuracy rather we need to have some kind of a coarser accuracies like 2 to 3 meter or 4 meter also acceptable. So, with this understanding, if I use a projected coordinate system there is no harm, I am very comfortable. Secondly, it is very easy to develop such application also related to projected coordinates ok. So, that is a that are the few reasons, they are not so only reasons, they are the few reasons where we need map projection.

One more example I can give you just imagine if you are a sailer like a Vasco Di Gama who is a selling in the sea from one country to another country right and so, you are going from one country to next, then what will happen once you reach to a someplace, you do not need more than 10 meter accuracy in that case fine map projected coordinates are or the map projection is also with you. At the same time, you need a map of very large area; that means, since you are crossing the sea or ocean well I hope that you understand the message that in this course, when we talk about map projection for the projected coordinates, we are going to do it for a very large area so that, I will have an understanding of a very large area that can for example, a city or state or maybe a country, well.

So, let us look what is a map projection. So, map projection is a mathematical function relating features on curve surface to features on a plane That means, I have a 2 dimensional coordinate system that is lambda and phi longitude latitude and I am converting them into some Cartesian coordinate x and y using some function of an transformation, ok. You may ask why should I convert it, when I know that lambda phi is very convenient to use. There is a reason for that.

And suppose, the reason is I ask you go 2 degree east and then go 2 degree north in the line of meridian and report me where you reach, very difficult. I think if you even assume that 1 degree is equal to 1, 110 kilometer so, you may think first of all how to go one 110 kilometer or 2 degrees means almost 220 kilometers in the each direction ok. Then going into north by again some degrees, very difficult, very un convenient.

So, but I ask you go take this map and go along the each direction by 100 kilometer or by 10 meter or maybe 10 kilometer, pretty easy for you and that is why we do the map projection; that means, we convert the longitude and latitude into Cartesian coordinate x and y, ok. We already know that accuracies are not there or rather we are compromising on the accuracies because of the projection, ok. One more information I would like to share with you at this instance when I express the longitude and latitude which is only 2-dimensional coordinate system, it is also called geographical coordinate system, ok.

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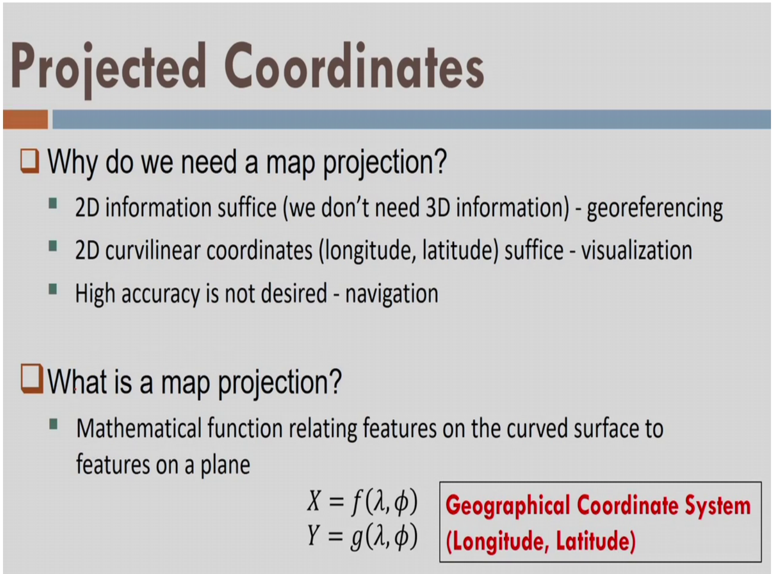

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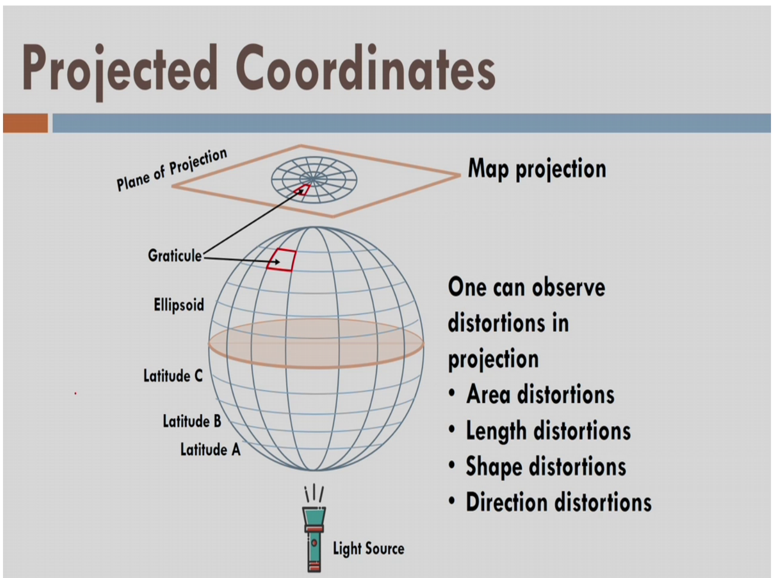

So, first projected coordinate system is I am showing you here, there is a plane of projection which is shown here and there is a ellipsoid shown here ok; one more thing is there that we are just showing ellipsoid; that means, we are not going to use the height that is ellipsoidal height, we are going to drop it ok. Even you can assume if there are two points which is not possible to have at one location and one longitude and latitude, a point can be very high that means, it can be 55 meter or it can be a 100 meter.

But at a given lambda phi you will have only one point on the surface of earth well since we remove this information. So, the point which is lying on the surface of a earth, now it is lying on the ellipsoid ok. You can assume like that, fine. So, before we go ahead, there are few terms for example, latitude what we call as a parallel of latitude since the latitude A that means, it is a parallel of latitude where latitude is not going to vary and it will be remains same as shown by let us say, a Latitude A, same way Latitude B, Latitude C is there and then we have a Graticule. The Graticule is a box formed by the intersection of meridian line and the parallel of latitudes or I can say a latitude line.

So, this is a one graticule. So, there are many graticules shown on the ellipsoid ok. Now, let us say there is a light source which is I put at the bottom of South Pole South Pole of the ellipsoid and now because of the light source what will happen, the light because of light source all the lights will go like this and they will project the points on this plane of projection and because of that you will get some kind of figure. So, let us try to make those figure. So, this is the light is exactly below the South Pole, South Pole South Pole will appear as a dot like this shown in the figure, on the plane of projection, ok.

The next that is parallels latitude will appear like that circle because it is a kind of circle here and light is projecting on this thing third latitude B, latitude C. Now I have projected and maybe ellipse, I can also shown the equator, but what about the other meridian which are vertical lines passing through North Pole to South Pole, right and they are also touching the equator what about those. They will appear as a straight line, now you can imagine that just imagine that this is a light source which is projecting the straight lines or the curvilinear meridian lines from the South Pole South Pole to diverging out.

So, hence I will have this kind of lines ok, what about the graticule? So, this is my Garticule here well I hope that you got the idea, what is the map projection and you can now develop your own map projection or you can imagine if I give you where is the light source, how will episode placed and where my plane is placed. So, once three things is clear to me or clear to you to any one, we can imagine how a map projection is developed, well. This is a quite complicated mathematically.

But, now a days there are many faculties available, ok. Before that, so it is I call map projection or the projected coordinate, the better name is map projection you can observer here that areas are distorted; for example, I am showing you a graticule. It is now distorted in the map projection. Same way, length is also distorted; that means, the length is not no more a true length which is on the surface of ellipsoid. It is no more reflected or a two length, there on the map projection, shape is also distorted that means, the angle between the two lines, I can say the angle between latitude line and meridian line is distorted now.

Direction distortions; that means, the azimuth of a line is also distorted from the ellipsoid and now when it is projected to the map projection, well. So, we have understood what are the drawbacks or what are the limitations of map projection, but still with these given limitations, we would like to use because they provide some kind of facilities which are not available otherwise.

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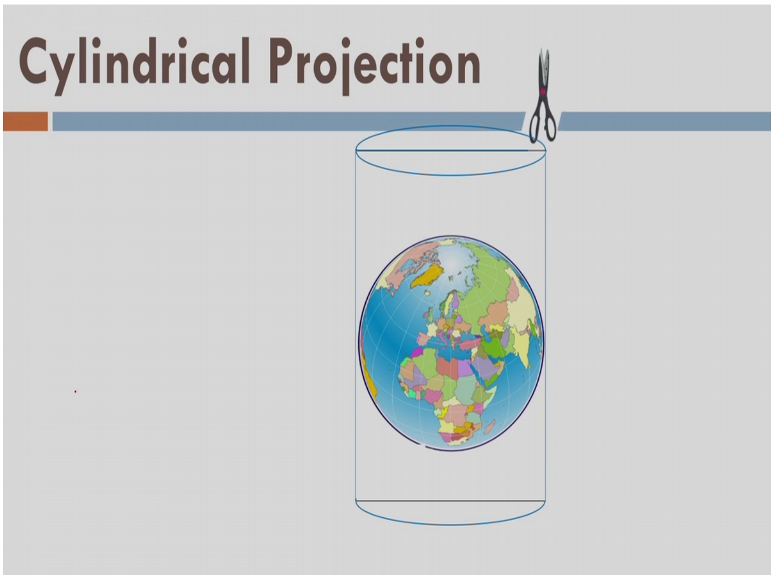

So, let us see in the last slide as seen I have shown you that I am projecting the surface on the plane that is the map projection or the plane of projection is a plane. Can I project on a curvilinear surface; for example, cylinder yes I can. So, let us see that I place an ellipsoid into a cylinder which is of so big covering the whole earth for a whole it is ellipsoid. So, those points which are lying on the ellipsoid, I projected exactly on the surface of the cylinder. And now, I cut the cylinder and I unfold it ok, you can imagine there is a one wrapper like a paper that which is which is of shape cylinder.

And now, you are projecting your ellipsoid on to that paper and then paper you unfold it again. So, how will it appear, let us look into animation. So, let us say I have cut down the cylinder and then I am unfolding it.

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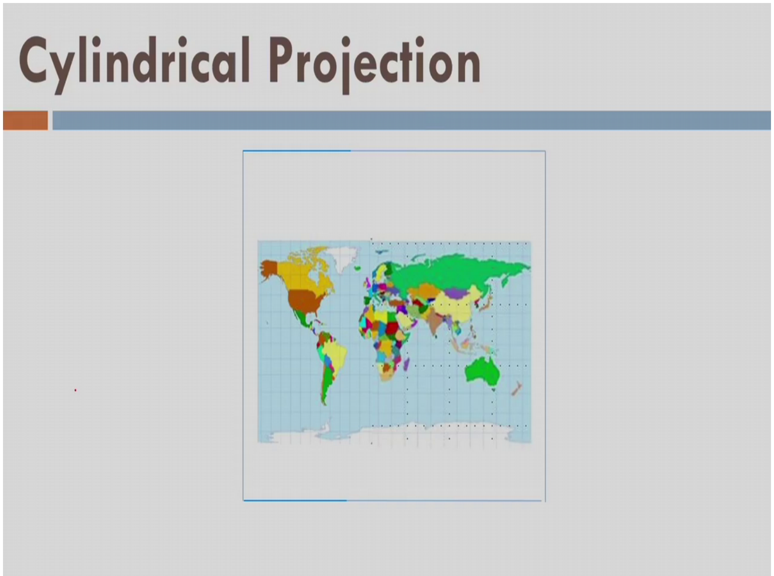

So, since the all the projected points which are projected on the surface of cylinder, now it will open like this like a unfolding of book or rather you are unfolding the cylinders like this. So, this is what is cylindrical projection and which we are doing on a curvilinear surface.

Similarly, instead of cylinder I can also use cone, well. In case of cone, I will cut a cone from it is lower edge to the vertices and then I will unfold it ok. So, let us look all this things into coming slides. So, the general properties

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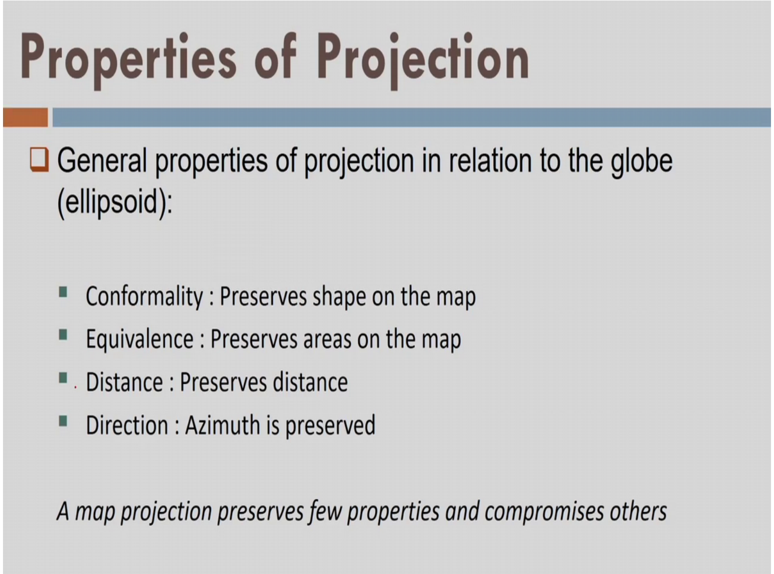

Of projection system is conformality; that means, I want to preserve the shape of the map well, what is the shape on the map? Remember I told what are the distortion, similarly, out of those distortions at least I would like to ensure a one property should be secured. That means, if I am want to secure conformality that means, I am going to maintain the same angle between the two lines before projection and a after projection

So, let us see if there are two lines at 90 degree before projection, after projection they will maintain the same angle in the map and hence I will say this is the conformality property; that means, the map is a conformal ok. What about the equivalence, equivalence is preserving area; that means, the size of area is same before and after, distance is if the length of a line between two points is same before and after the map projection, then it is called distance preserving or sometimes we called it a scale preserving also. Direction is azimuth that is a line with respect to the north direction is preserved then we call it in the direction preserving map projection ok.

A map projection can ensure a few properties and sometimes it does not ensure even one, but at least I am very sure and you will also be come to know that none of the projection can ensure all the properties. So, they may ensure a few of them and they compromises on the other. So, let us see the classification.

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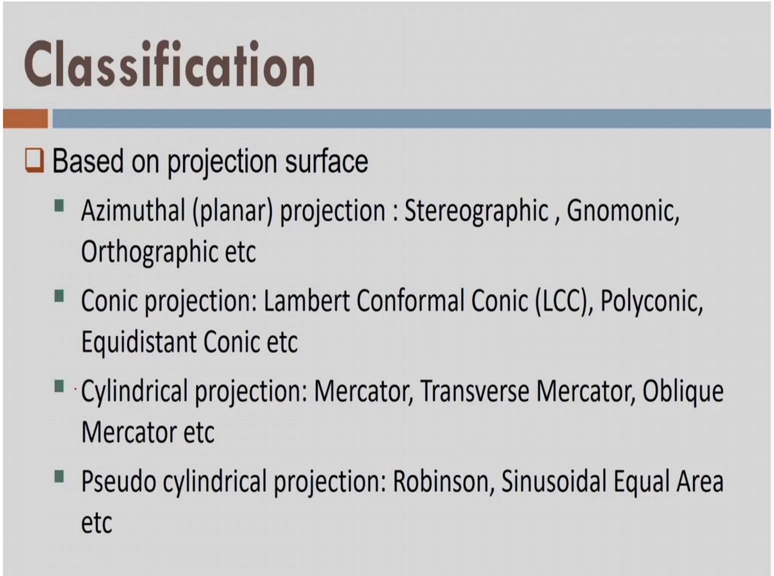

So, it is based on the projection surface. So, as I shown you before planar projection; that means, the plane of projection is plane ok, conic projection it is plane of projection is conic and then cylindrical projection, if projection of surface is a cylindrical.

Further, we have pseudo cylindrical projection. Remember I gave you an example of pseudo, what is the means. In the movie, based on character who looks like exactly the main character or the hero, but he behaves slightly different. So, such a thing we called pseudo. So, there is some projection which is looks like cylindrical, but it does not fulfill all the criteria's of the cylindrical projection, but still we call it pseudo cylindrical projection.

So, we will going to look into all this kind of projections into this lecture ok. In case of Azimuthal, Stereographic, Gnomonic, Orthographic they have the name, in case of Conic projection, LCC, polyconic Equidistant Conic, they are the examples here. Cylindrical, we have Mercator, Transverse Mercator, Oblique Mercator and then Robinson, Sinusoidal and Sinusoidal Equal Area projection are the example of pseudo cylindrical. Well, in this lecture we are going to look at the few of them and their transformations between the two.

So, there is a distortions as we discussed.

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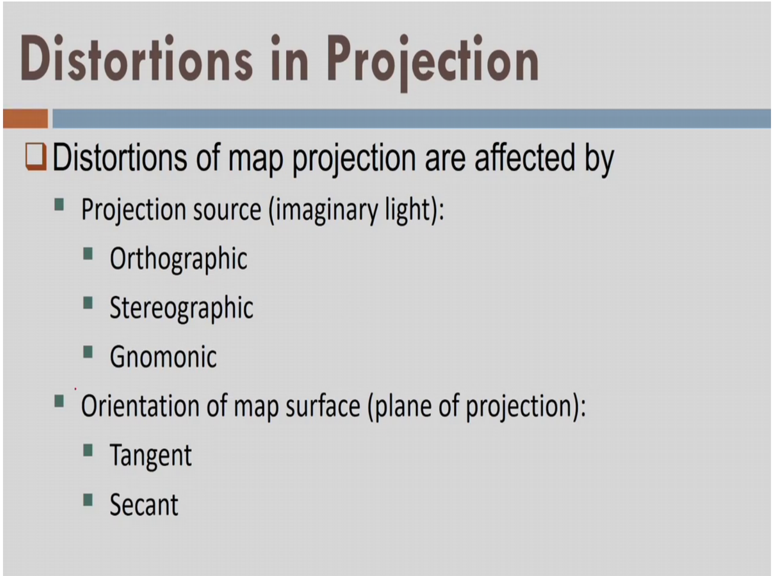

So, distortions of map projections are affected by the imaginary light where we put the light remember ok. So, we have like Orthographic Stereographic or Gnomonic projection. They have different point of light source, then orientation of map surface that if where I place the plane of projection ok. One term is called tangent and one is called skit. If my plane of projection if it cuts the surface of earth, I call it a secant; that means, it is going to touch at two places is case if it cuts. But if it is touching at a only a one point, for example, cylinder is touching at a equator only, then I call it tangent ok.

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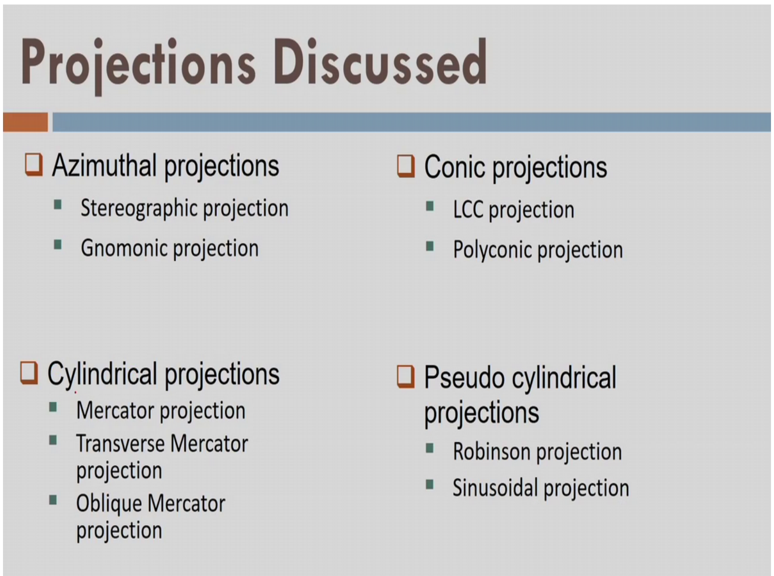

In this lecture, we are going to discuss these few of the projection map projection system here. So, let us go one by one.

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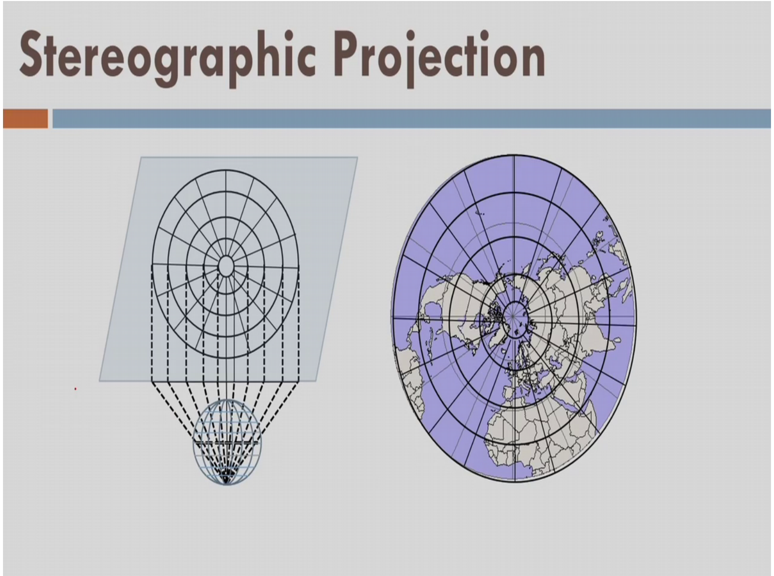

So, of a azimuthal projection where the stereographic projection is there in case of a stereographic projection, I have a light source at the exactly at the South Pole South Pole and it is trying to project the area of ellipsoid above equator and equator. So, there will be a equator that is going to made a circle after projection and all the latitudes or rectangular of latitude above equator, they will be appearing as circles as we can show in the figure ok.

What about the north pole? North Pole will be appearing as the one point because the light source is exactly below there, fine. So, that on the right hand side, they have shown one example of how will map look like if I am using a stereographic projection for an surface of earth ok.

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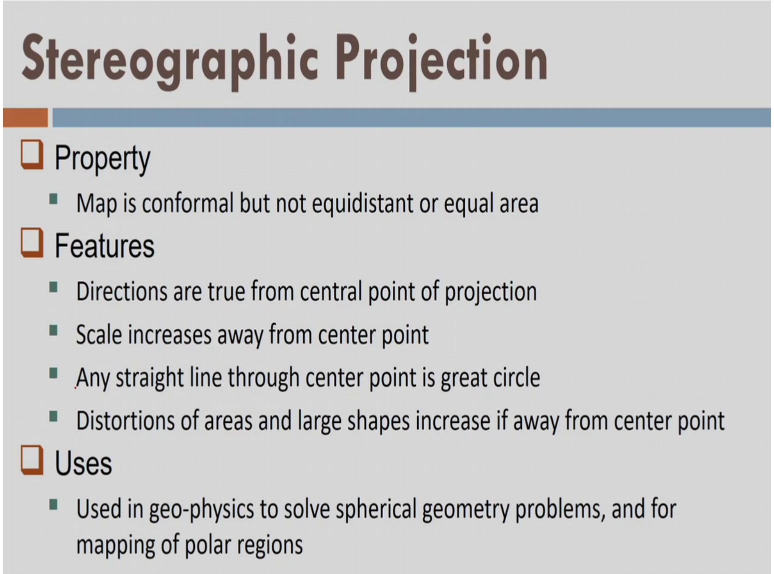

So, this there are some properties; in this map projection, we ensure that this map projection is conformal; that means, deliberately it is ensure that the two lines if they have some angle theta between them the angle between them should remain theta even after projection.

And because of that, we call it conformal property. So, after ensuring this conformal property, we get some features like directions are true from the central point of projection. The North Pole because it has central point of projection of north pole. So, from the north pole all the directions are preserved, in a sense, directions are true for example, if I take all the meridians the distances between the angular distance between the meridian before and after they will remains same.

A scale increases away from the central point if I go away from the north point or the central point of projection on the map, then the shorter distances will be shown by the longer distances ok. Any straight line through the center point is great circle ok, now we can imagine that all the meridians which are great circles. So, they are originating from the north pole, they will appear as a straight line because thereby the circuit is out from the North Pole like this.

Distortions of area and large shapes increase if away from the center point because as I said that distortions of the lines are increasing as we go away from the north pole. Automatically, areas will also be distorted because area is the combination of two lines in different direction ok. What is the use of this map, such a map is used for geo physics to solve spherical geometry problems and for a mapping of polar regions. Now, we can imagine that this stereographic projection, it is not distorted at a North Pole why because North Pole is completely intact layer or completely projected without any error.

And as a result, I should use it for the polar regions. In case of South Pole, I will put the light on the North Pole and I will project all the light rays from the North Pole towards South Pole South Pole and I can plot the map like that. So, that is the idea here that we want to have minimum distortions and as a result we use a certain type of map projection in certain area of earth only and that is the reason we have a lot many type of projections and we have to understand which projection is appropriate for a which area. So, that is a idea here of this lecture.

So, before taking any decision, anywhere if you go to some other country also, you should know that why this particular country is using particular type of projection, well let us do ahead.

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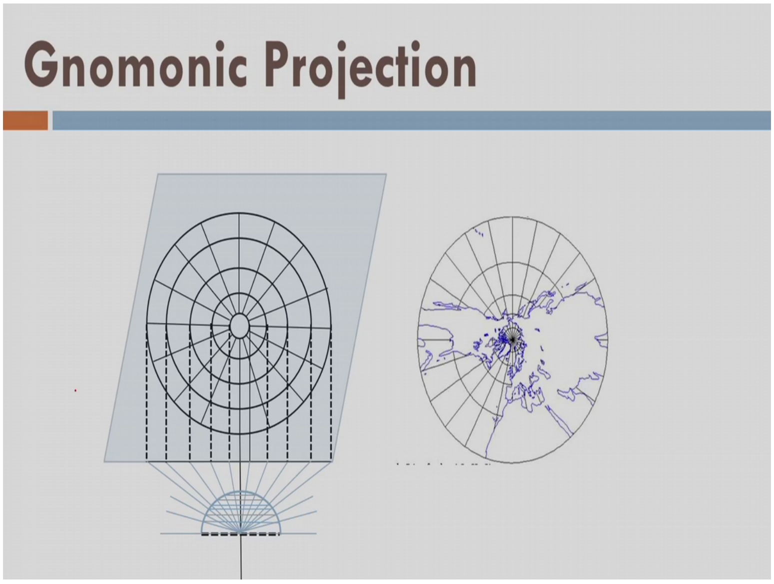

Next is Gnomonic projection which is again a planar or a Azimuthal projection here, you see the light source is put on the center of the ellipsoid and as a result, it is not projecting the equator or rather it will project the equator at the infinity. So, that will not be a visible in the map.

So, all other parallel of latitudes which are parallel to the equator are projected in the form of circles, again North Pole is again projected without any error right and now you see on the right hand side, there is a example of a gnomonic projection.

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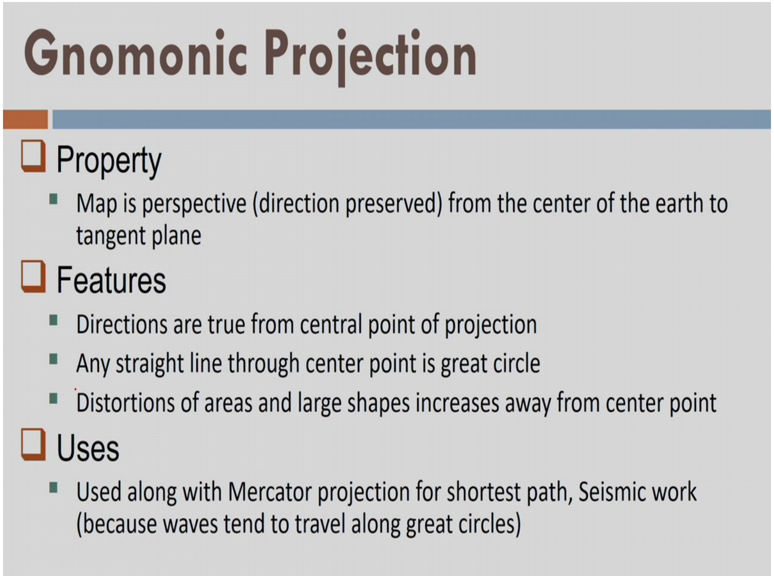

The properties again the map is perspective that is direction is preserved direction from the North Pole that is from the center of earth to the tangent plane ok. So, tangent plane is nowhere it is I put let us say at a I put at the North Pole flat to the equator, parallel to the equator like this.

So, in this plane, we have directions preserved. So, what are the features if I ensured this property? So, directions are true from the central point of projection which is similar to the stereographic projection, any straight line through the center is great circle, distortions of areas and large shapes increases away from a center point ok. So, now, uses are used along with the Mercator projection for a shortest path and seismic work because waves tend to travel along the great circle. That is a kind of assumption, seismologist make and that is the reason we prefer to use it for the a study of seismic work or for the earthquake studies and so on.

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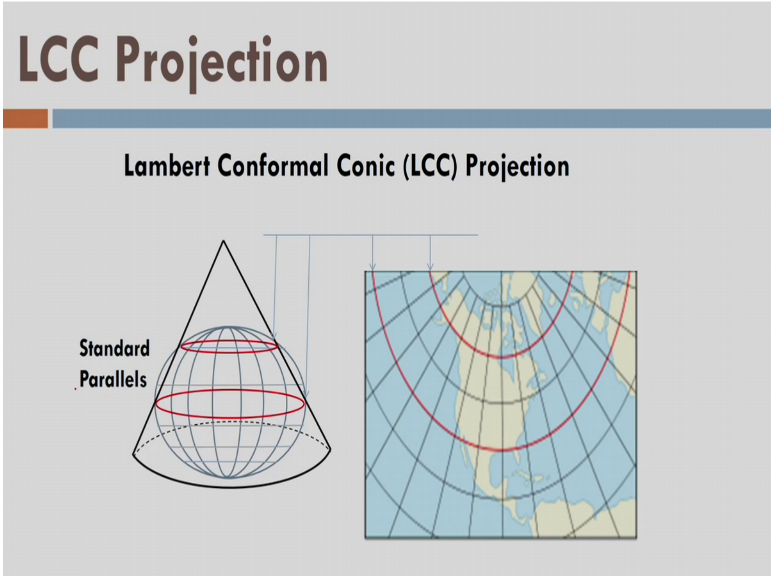

Now, we go to the conic projection that is another class. In the conic projection, the first projection is Lambert Conformal Conic Projection. Here, you can see it is a second type of a system; that means, it is cutting the plane of projection is cone and cone is cutting the ellipsoid at two places, at two parallel of latitude. These two latitudes are marked in red color. Now you can, see these parallels where the cone is cutting the ellipsoid are called Standard Parallel. So, in this case I called standard parallel 1 and is standard parallel 2, fine.

If I look at how these are projected on the surface of cone, so you can see that the parallel of latitudes which are appearing almost parallel to equator in the circular form when they are projected, they are appearing as a curvilinear line on the map surface. So, the same red lines are donated by the red lines in the map projection and some arrows are indicating how they are being transferred ok. That means, once you project your map projection, that is ellipsoid on to the conic surface, cut it, unfold the conic surface, it will appear like that.

So, wherever the projection plane touches the surface of a ellipsoid, we will get minimum distortions in the same fashion, since the cone is cutting at two or rather it is touching the ellipsoid at two places; once is standard parallel 1 and another is standard parallel 2. So, I will get minimum distortion at these two standard parallels ok.

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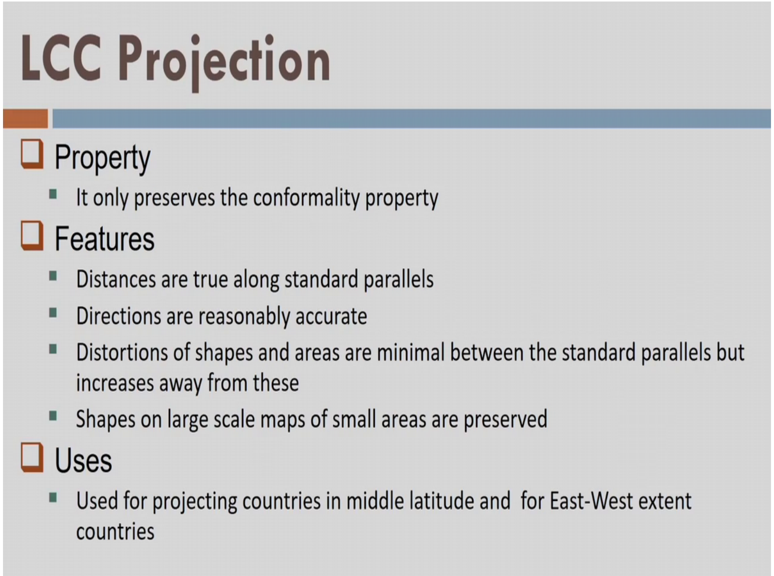

So, directions are reasonably accurate, distortions of the shapes and area are minimal between the standard parallels, but increases away from these. What is a meaning here?

Let us see there are two standard parallels and I told that at these standard parallels, I will have minimum distortions. So, let us see the standard parallel 1. So, as I go away like this, I will have distortions for this lower one or these standard parallel two as I go away, I will have distortions. Now, distortions between the two standard parallels will come to the maximum somewhere in the middle part where if I limit that maximum distortion to some limit, then I can easily utilize these two standard parallels or the between area between the two standard parallel for this map projection.

And that is somehow an advantage of this. We will see why ok. Now, what happens above this standard parallel 1 and what how happens below this standard parallel 2. Here, distortions are keep on increasing well and here distortions are keep on increasing and I cannot limit them also by some way and as a result this is somewhere it gives me some advantage for a middle latitude country. We will see why. Ok, the shapes on the large scale maps of small area are preserved.

Now, as I told the then the advantage of this one for the middle latitude countries because distortions can be limited to a certain value and as a result between the two standard parallel whichever countries are falling, I can use this map projection for those countries. Remember, in a middle latitude our country India also lies and as a result of that, the survey of India topologies are having LCC projection, fine. So, even some countries like which are extending in east west, but at the same time they are lying in the middle latitude, ok. There is some country which is area has like this along the east west more, then and it is also falling in the middle latitude, maybe parallel to India also then we should use this LCC projection for that country also

So, let us go ahead. There is another type of conic projection which is Polyconic Projection.

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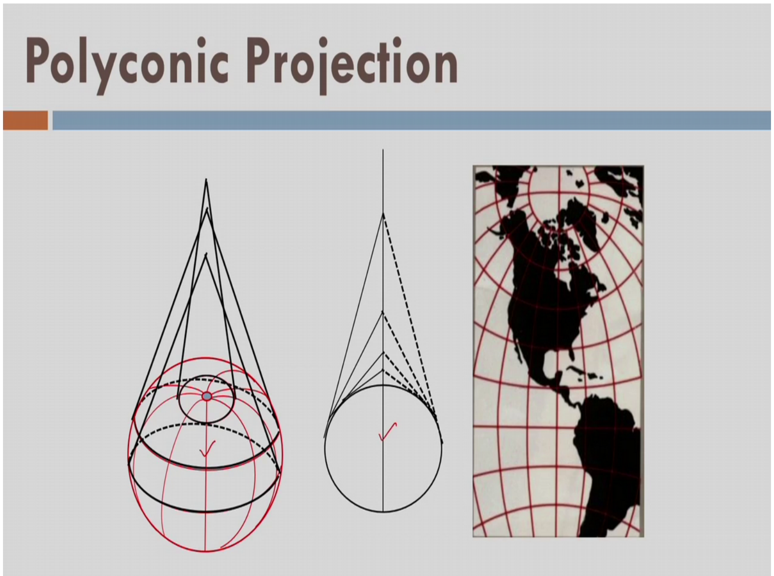

So, Polyconic Projection is like that, there is a ellipsoid and I have this course which is touching at certain latitude, there is another cone which is touching it is certain other latitudes and this sort of one more cone and so, I am represented here. You can see that there is a middle line here, this line which is I am putting it here, take this line it is shown here and that is not distorted and because of this I can say along this particular meridian, distortions are minimum, even there are three cones, ok.

Moreover, if I see the three cones are touching the three latitudes or even if there is a one cone it is touching certain latitude, fine there will be minimum distortion. So, this is an example of the Polyconic Projection. So, what are the properties here.

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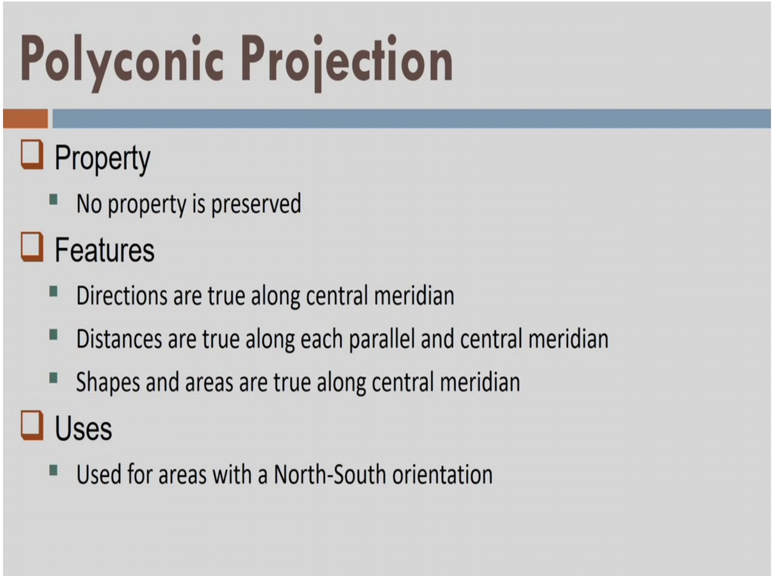

There is first of all no property is preserved here. So, whatever mathematics we do with this projection system, we cannot secure or we cannot preserve any property here.

But still we get some features like directions are true along central meridian. As we have seen that along the central meridian, distortions are minimum. Distances are true along each parallel and central meridian well. Still, I am getting some of the things very correct shapes and areas are true along central meridian. That is a good enough for certain purposes and as a result it is used for the area with the north south orientation and here middle latitudes are not important ok. If it is a middle latitudes since we are using a cone, that is also fine, no problem.

But most of the time for the country like India which is expanding more in the north south compared to east west, this kind of Polyconic Projection is recommended. Now, Mercator projection that is a class of cylindrical projection and we have already discussed in the animation. So, let us see little more into that.

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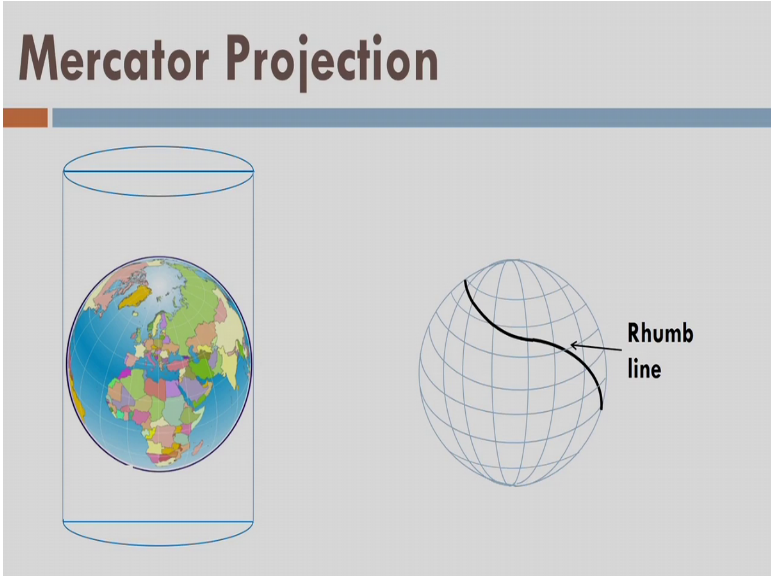

So, there is a Mercator projection shown here; that means, there is a cylinder which is covering the ellipsoid and now I am going to project the ellipsoidal points on to the cylinder

Now, there is a term called Rhumb line comes here and which is very important to understand. So, a Rhumb line has been shown here and you can see that the Rhumb line is maintaining the same angle well with each and every meridian and that is the advantage. This is the way we define the Rhumb line ok; that means, if you see this angle here and the angle this angle you can see here where my point is in pointing out and this angle with each and every meridian, it is same.

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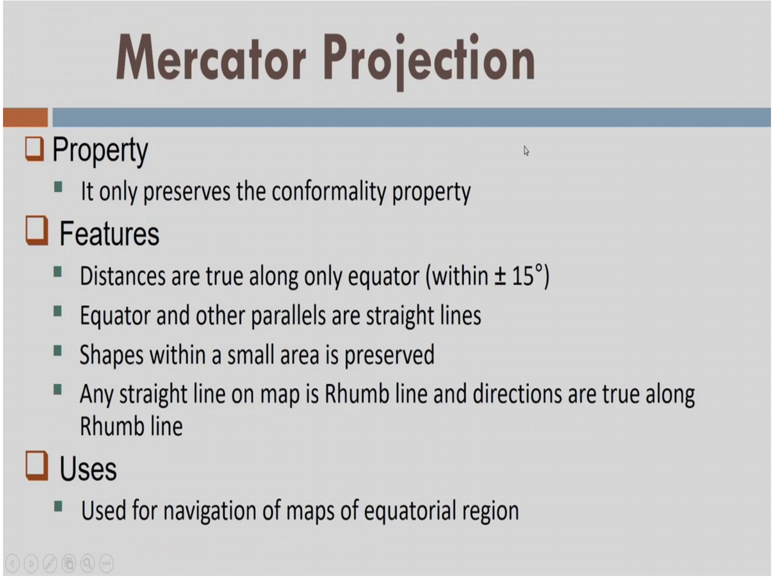

So, now, let us look into the property of Mercator projection. Property is it only preserves the conformality property when distances are true along only equator within plus minus 15 degree is a, now we can understand with conic projection and stereographic projection as explained if the surface of projection or the projection surface touches the ellipsoid at that point, we have maximum or a minimum distortion or the maximum properties are preserved.

So, here since the cylinder is touching the equator, around a equator we will have minimum distortions. So, distances are true along only equator within plus minus 15 degree equator and other parallels are straight lines you, can imagine. On the cylinder, they will appear as a straight line because they have been projected like that. Shapes within a small area is preserved any straight line on a map is a Rhumb line and directions are true along a Rhumb line, the Rhumb line as I told it is maintaining the same angle with the meridians, ok.

Now, since it is a conformal. So, you can find out the Rhumb line will be a straight line ok. The uses are it is used for navigation of maps of equatorial region; that means, from where it our country is around equator, we should use this Mercator projection for that country or region and within plus minus 15 degree, we will find minimum distortions, coming to the transverse Mercator projection, this type of projection.

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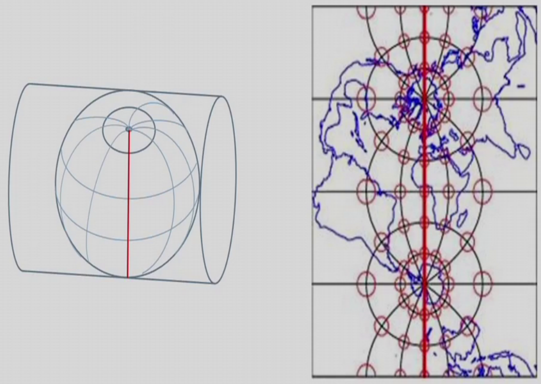
Transverse Mercator Projection



Now, you can imagine I want to have the same properties for some countries which are not at the equator rather they are of the equator along certain central meridian.

So, what will I do? I have tilted my cylinder from vertical to horizontal and as a result now, cylinder is touching certain central meridian or certain particular meridian over a country. For that particular central meridian which I am calling central meridian, I can have within plus minus 15 degree minimum distortion. So, now, this is the property; it preserves the conformality property.

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Transverse Mercator Projection

- Property
  - It preserves the conformality property
- Features
  - Distances are true along central meridian
  - Distance, direction, shape and areas are accurate within ± 15^0 of the central meridian
  - Graticule spacing increases away from central meridian
- Uses
  - Used for mapping large areas that are mainly North-South extent

Distances are true along the central meridian ok. Now, you can imagine how nice it is to understand any central, any map projection, distance, direction, shape and areas are accurate within plus minus 15 degree of the central meridian as I already told you.

Graticule spacing increases away from the central meridian, what does it mean? As I shown in the first slide what is the Graticule spacing. Now, if we go away from this central meridian like this, you will have more distortions in the Graticule spacing or the area fine. It is used for nothing a large areas that are mainly north south extent. Now, you can imagine easily why we are using transverse Mercator for the some countries like which are extended in north south.

UTM, what we call Universal Transverse Mercator.

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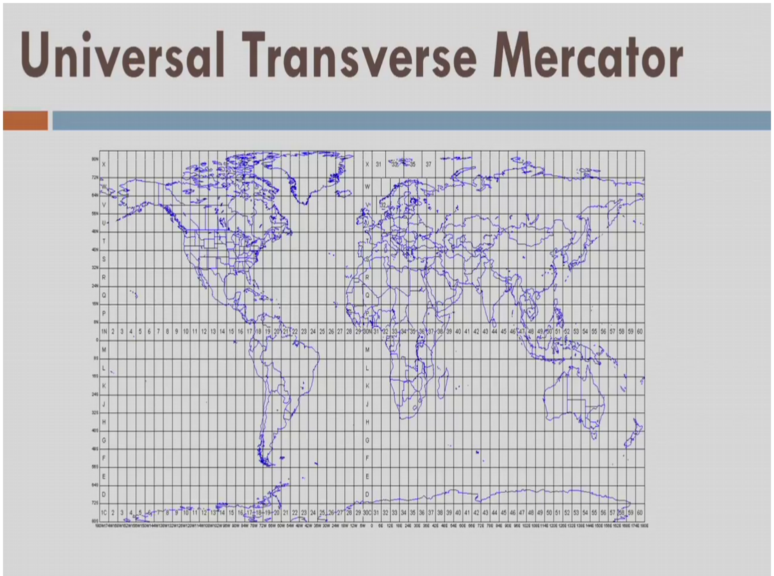

It is a particular type of or the specific example of transverse Mercator projection systems ok. UTM is now most popular map projection system which is being used mostly now, especially including GPS and GNS services, perhaps your map projection system that you are using in your mobile phones or also might be using UTM only ok. So, in this UTM, the picture is shown.

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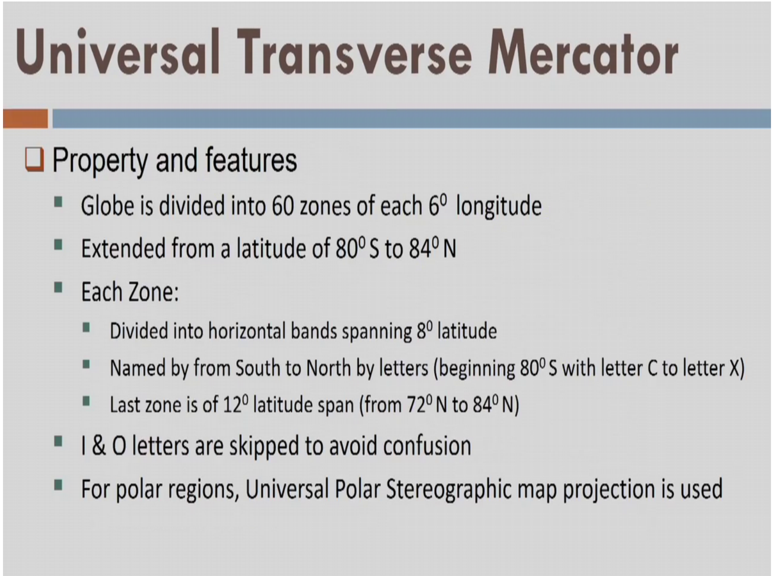

You can get a lot of literature about that pretty easy to understand.

So, properties and features are like globe is divided into 60 zones, that is ellipsoid is divided into 60 zones each of 60 degree longitude. So, I have 60 such zones which are divided each of with 60 degree long, 6 degree longitude, 6 degree, 6 degree, 6 degree all along the equator. So, it is extended from latitude of 80 degree south to 84 degree north; that means, these are the latitudes these zones, vertical zones are extending from 80 degree south to 84 degree north ok.

So, each zone, now I am dividing the zones in horizontal way also now, right. So, these zones are divided into a horizontal bands spanning a 8 degree latitude. So, what does it mean? This is 6 degree longitude zone and 8 degree latitude zone ok. So, this is a 8 degree span and this is 6 degree span. So, now, I have many such zones on the UTM map projection. Secondly, these projections are limited between 80 degree south and 84 degree north, ok.

So, we are starting for this kind of bands which are 8 degree in the latitude span with the word C at 80 degree south and there is a last word X at the last zone which is starting from 72 degree and it is not 8 degree wide rather, it is 12 degree wide fine. So, we can see here all this thing and secondly, we have avoided the word I and O which are generally used for input and output and many other things. So, now, we have so many zones and so on, ok.

What about the polar regions; that means, which is above 84 degree north and below 80 deg[ree]- 80 degree south, for those polar regions we have using we a we use a stereographic map projection, but we have given on the similar fashion, the name universal polar stereographic map projection again which is an a specific example of a stereographic projection and there we do not use UTM, we use UPS there, fine.

Now, you can understand very easily why UTM is so popular ok. What about the other meridians? That means, suppose there is a great circle along which a country is lined in north south direction; that means, which is not along the central meridian rather it is on this some other line which is shown here by a red color.

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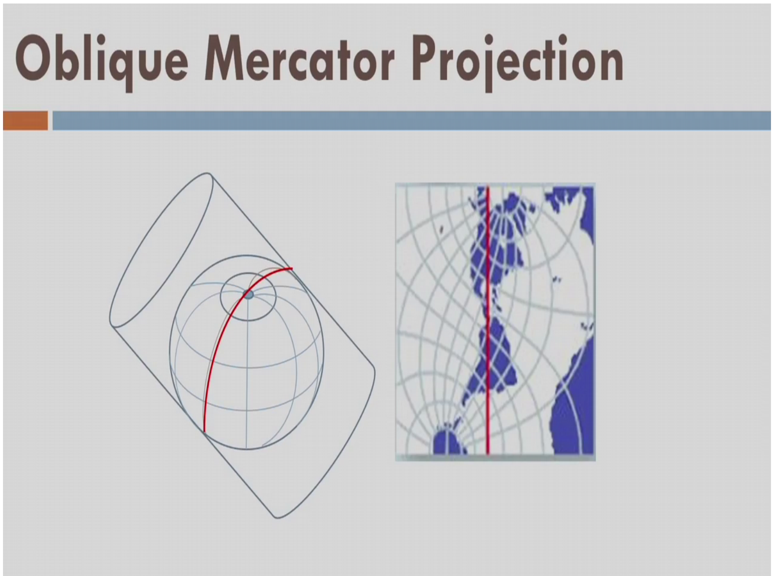

For example, it is see here where the earth is moving here ok. Now, for this Obliques Mercator Projection, I can ensure the same property by tilting the cylinder since tilt cylinder is tilted it is going to cut the ellipsoid, at certain great circle, ok.

So, a particular country which is having a great circle at the center of their line of a country, they will use this kind of oblique Mercator profession and it has again conformal.

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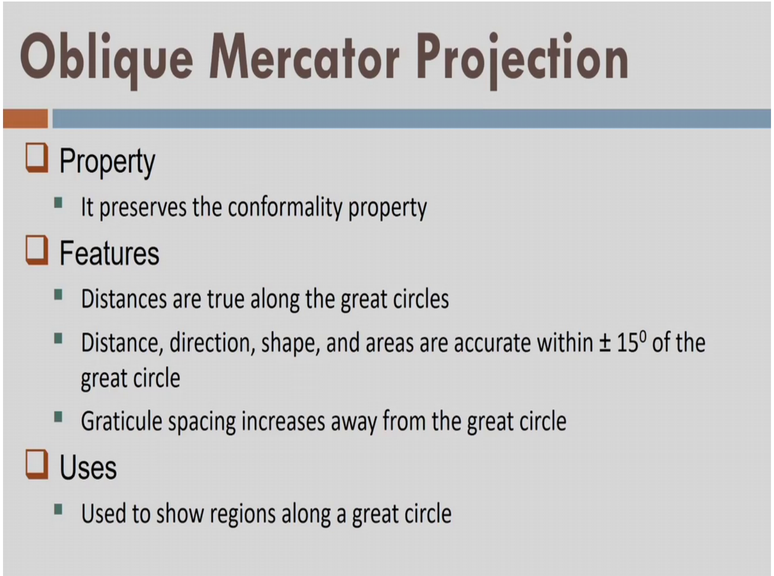

Distances are true along the great circle that particular great circle distances, direction shape and areas are accurate within plus minus 15 degree of the great circle. Graticule spacing increases away from the great circle here.

Now, we can imagine that three cylindrical projections; one is Mercator, then transverse Mercator and then the oblique Mercator. They are more or less similar, but only difference is they are having different orientation and what is a use used to show regions along a great circle; that means, a certain country or certain area which is lying across a great circle not across a certain meridian, then we will use Oblique Mercator Projection for the reason or area.

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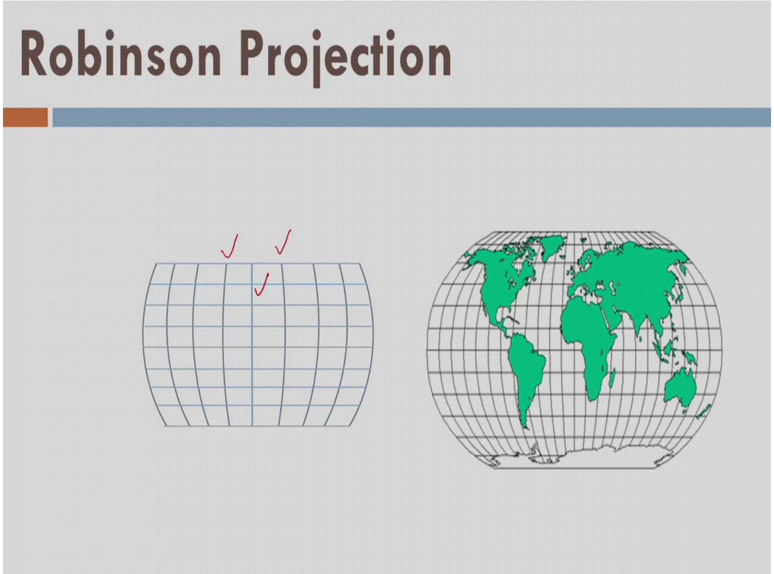

Now, let us come to the fourth category of map projection system that is Robinson Projection and this projection, we can see here there is a some meridians shown here and this is central meridian, ok.

All these meridians are cut between two layers of a cylinder; that means, this cylinder here and now I have a cut it at two places and between these two all the meridians are projected and because of that, we get this kind of map projection shown in the right hand side.

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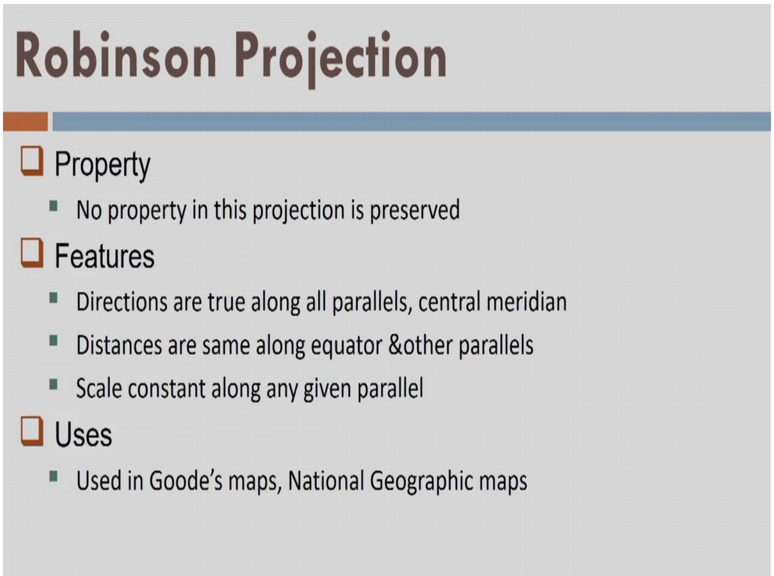

Property, no properties in this projection is preserved that are the features. Directions are true along all parallels and central meridians; remember there is a one central meridian which is appearing as a straight line.

So, directions are true along all parallels which are like that because they are also straight line and central meridian which is of straight line. So, distances are same along equator and other parallels ok, scale constant along any given parallels; that means, if I have a parallel which is straight line in the map projection, I will have same scale. So, what is the use? It is used for the next geographic maps and goodies map. We can search more about that, there is another pseudo cylindrical map projection where sinusoidal equal area projections there, ok.

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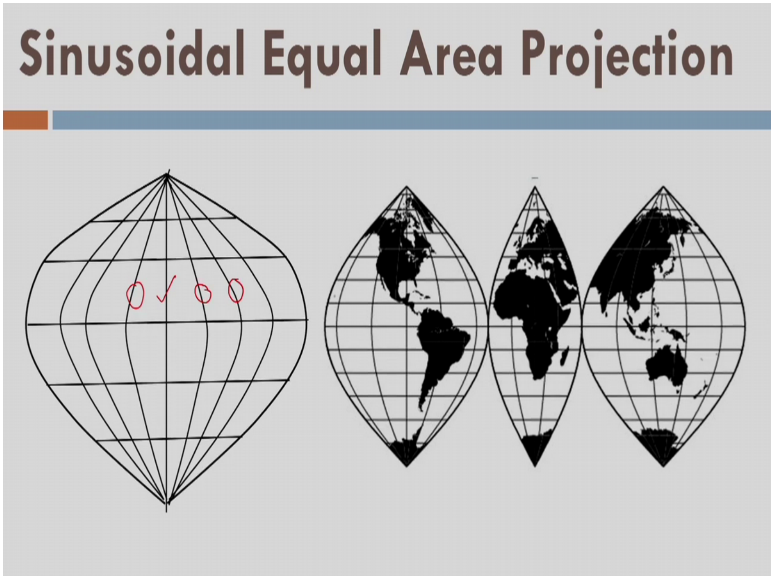

You can see these distorted lines of meridians here and so on, but this central meridian is straight line. So, I expect that the properties along this central meridian should be preserved or they will have a minimum distortion.

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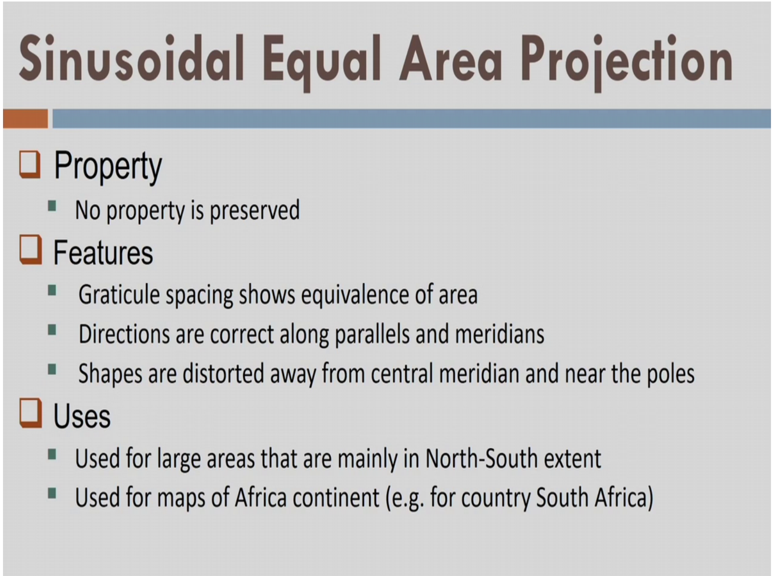

So, no property is preserved here. Graticule spacing shows equivalence of area; that means, whatever the area Graticule was having if they are projected on the map surface, they will have the same area or they will have minimum distortions. Directions are correct along parallels and meridians; as you can see, shapes are distorted away from central meridian and near the poles.

So, this kind of projection systems is not used for the polar regions; then what are the uses? Use for large area that are mainly in the north south extent, but not in the polar region fine, used for a maps of Africa continent, e.g. for South Africa.

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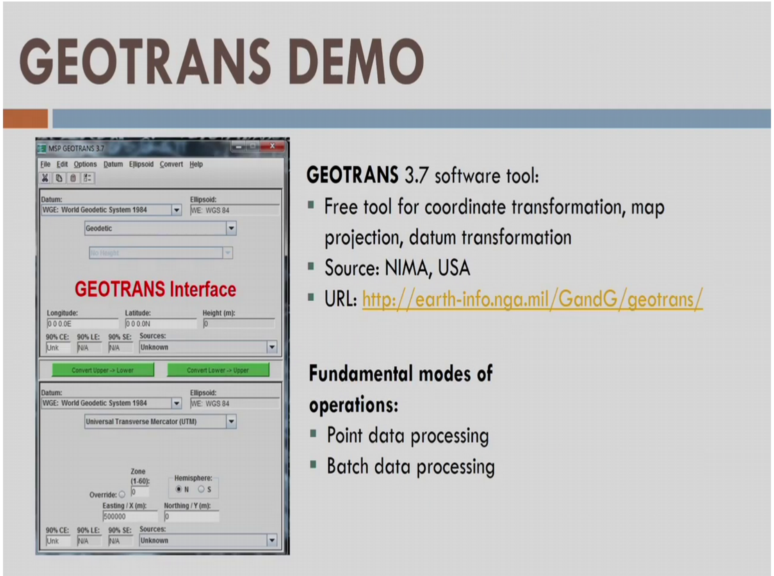

Now, we have application called Geotrans as we have already explained it in the last lecture, again this here in this lecture we are going to use it for the map projection, rather we are going to look from different perspective this time.

So, we have a point data processing and batch data processing.

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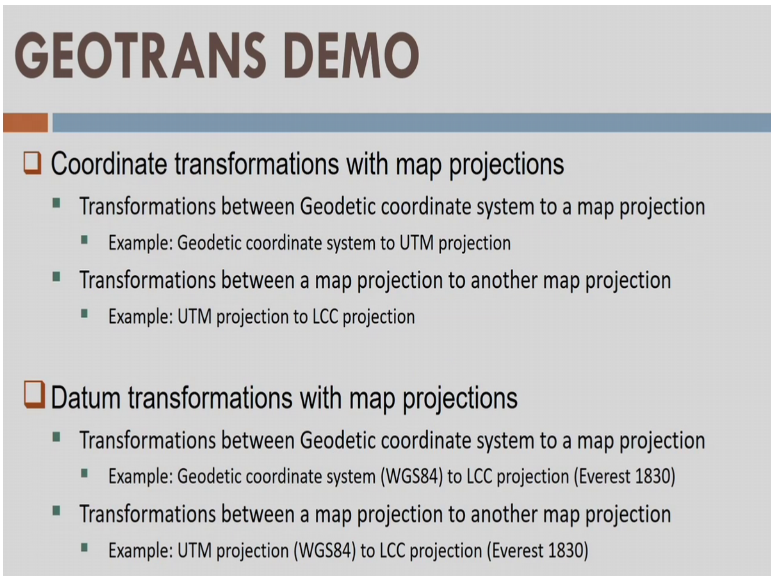

So, let us look into the point data processing and batch data processing for a map projection. So, we are going to cover that coordinate transformation with map projection as well as datum transformation with map projection.

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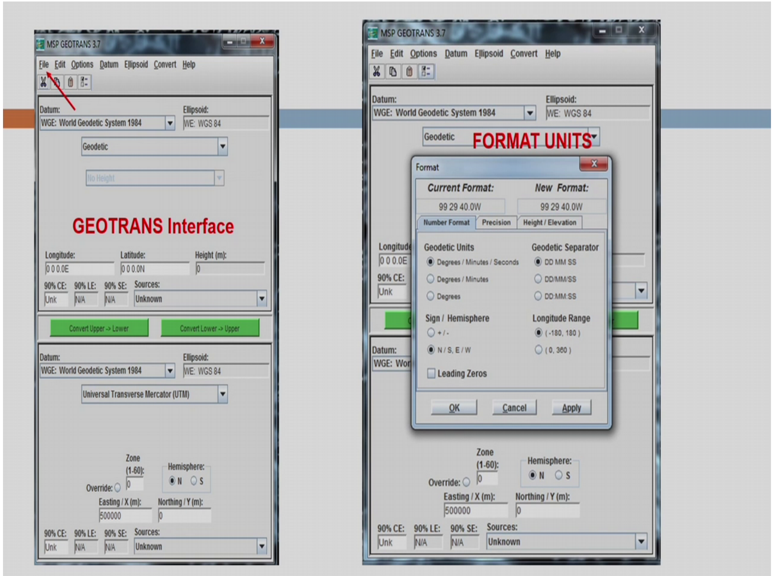

Now, this is a Geotrans interface and well this is a file and a how to format the units, you already know.

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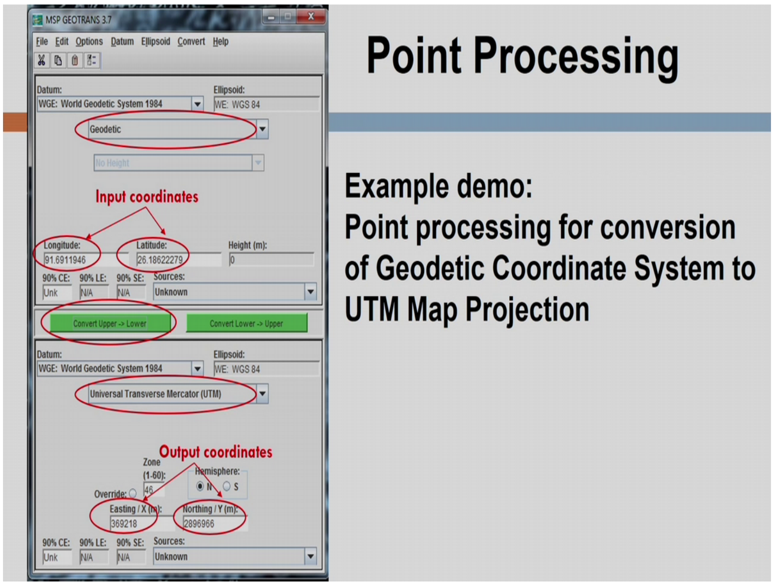

So let us go ahead ok.

Now, I am showing you the point processing that is we did not show or that I did not show in the last lecture. Here, we are showing a point processing for conversion of geodetic coordinate system to UTM map projection. So, first of all you will select here geodetic in the input and then you are specifying your input coordinate like this ok. Now, in the output, you will select UTM and there you are doing now, convert upward to lower by doing this you will get your answer here.

So, now you are have coordinates in the UTM map projection ok. Surprisingly, in the output and input we have same datum that is wgs 84 and so, we are saying this is the coordinate transformation in the map projection; that means, we are not doing any datum transformation now, ok.

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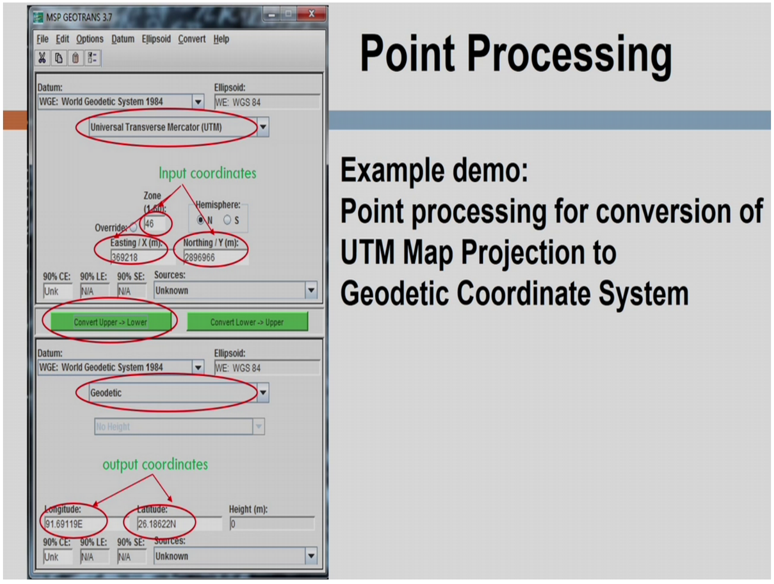

So, you are let us we go back or do the same thing in a reverse fashion; that means, I am converting the point in UTM map projection to geodetic coordinate system. So, what will I do here? I will specify my input in the UTM. These are the further information on the coordinates easting and northing and then I will choose geodetic in the output, then I will do convert upper to lower and it will give me the output coordinates.

I hope, you got what is the idea here for point data processing.

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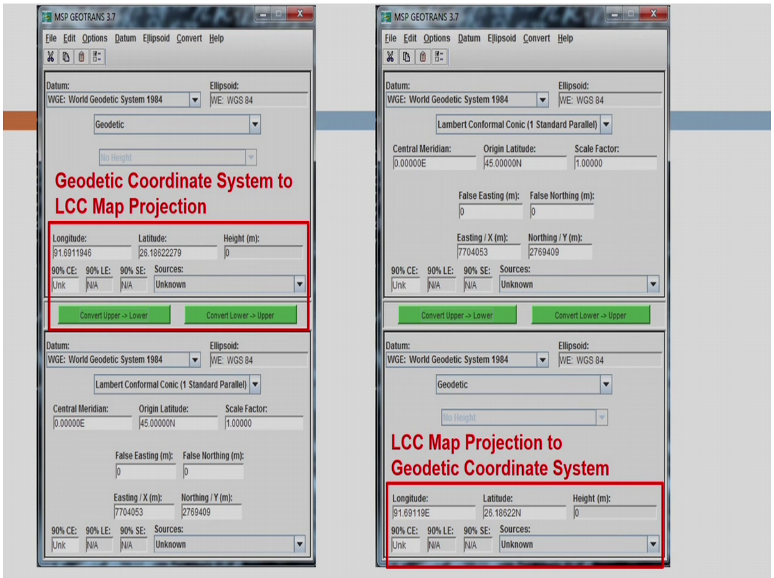

And what about the batch processing or what about the point data processing with other projections; let us see geodetic coordinate system to LCC map projection. Same process you will follow only in the output, you will select the Lambert conformal conic projection maybe the one standard parallel that is tangent system or maybe with two standard parallel.

So, example here shown with the one standard parallel, so on the left hand side, I am converting from geodetic to LCC map projection in the right hand side I am converting back from LCC map projection to the geodetic coordinate system. You can also try yourself, it is pretty easy.

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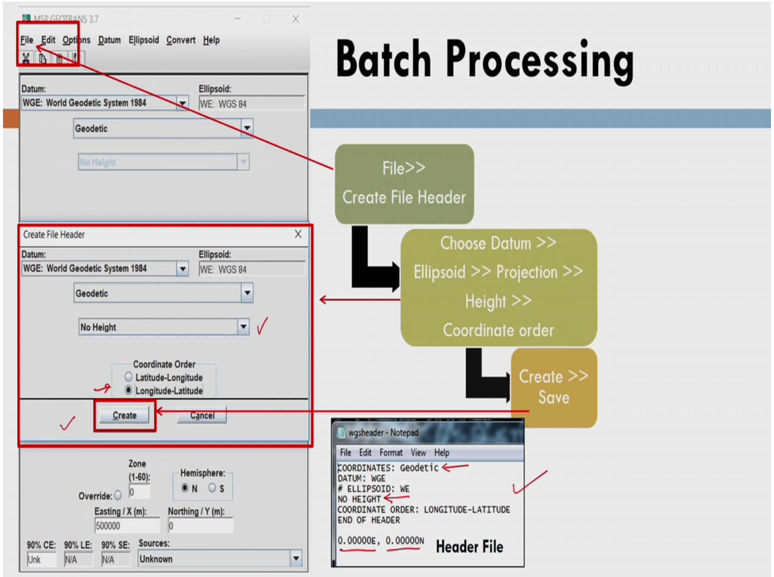

Yeah, the creating header file for the batch processing is same as we learnt in the last lecture. So, I am not explaining the process in the detail.

However, you should be very careful that we need to select no height for the map projection which means you are not taking into account the height of the point because it is a 2D map projection system. Moreover, so if we click on the create, so it will create a header file and this is the example of the header files here ok, the procedure is same and there you can see that this is my order which I selected here that is longitude and latitude.

And it is mentioning no height; that means, we do not in fact meet the height; however, it is saying geodetic coordinate system, it is 2-dimensional geodetic coordinate system what we call as geographical coordinate system.

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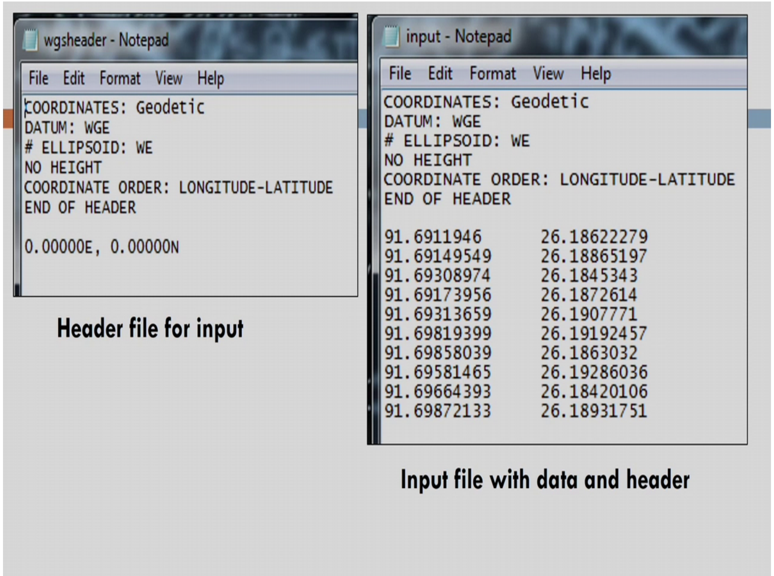

So, now, here we should be careful that this software is using a word geodetic with no height to indicate the 2 D geographical coordinate system. So, this is the header file for input and once I populate the header file with the data it will look like that.

So, I am putting a longitude and latitude in order for 10 points ok. So, this is my input files prepared for the map projection. Now, I will project these geodetic or the geographical coordinate of 10 points into some map projections maybe UTM, LCC, Polyconic and so on.

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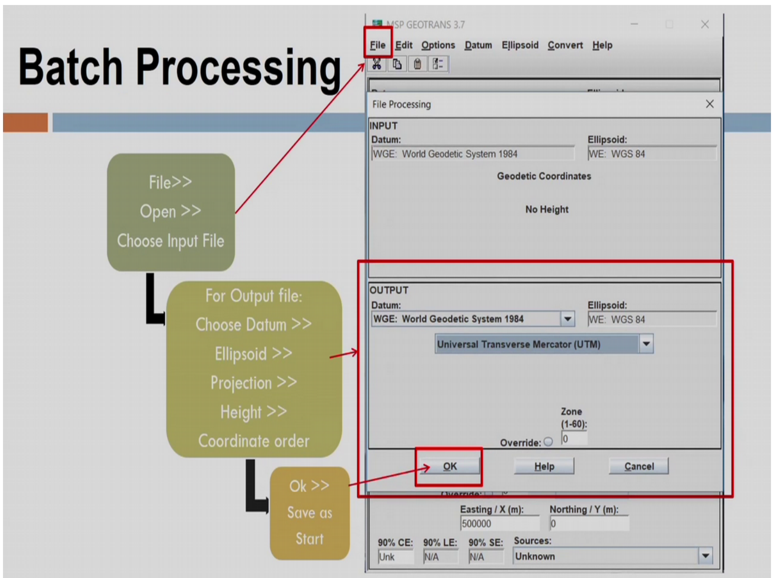

So, that is a batch processing for getting the output. You go to the file, you select the input file which you have recently prepared in the last slide and then you will select your output; that means, in the output you are selecting UTM because you want to project your geodetic 2 dimensional coordinates into UTM map projection x and y fine.

You once you click ok.

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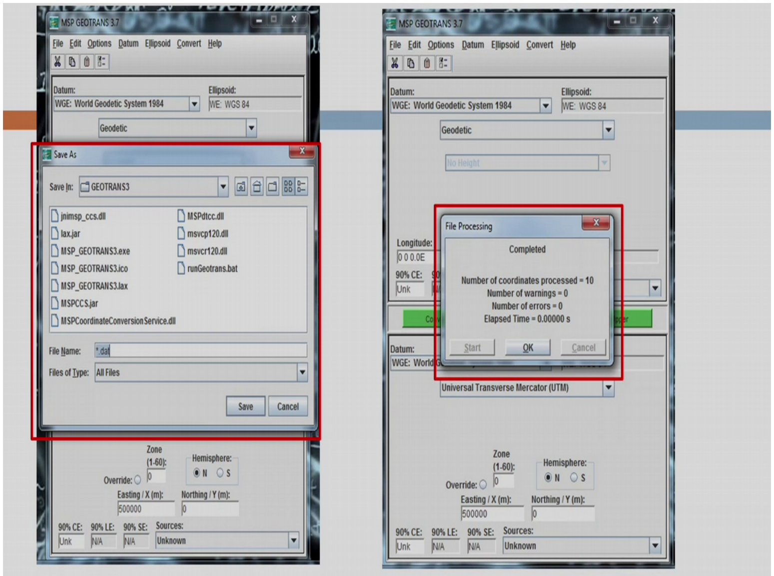

So, you will get this kind of a interface where you will save the output file and the moment you save the output file, there will be a message like number of coordinates process they are 10 and it is also giving you there are no warnings, there are no error and the time you left is minimum time, well. Now you can populate your files, input files with plenty of coordinate and now you use it. In that case, you should weight for some time because this application will take some time to process your data because the data is in plenty.

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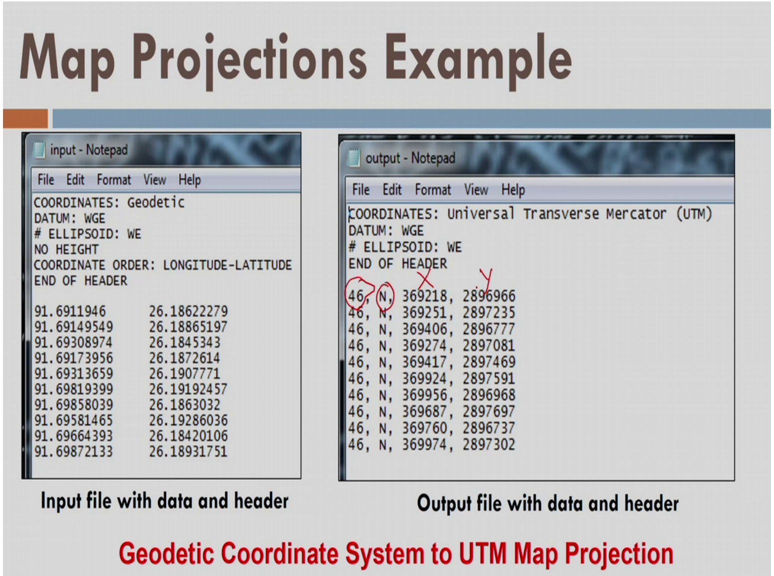

So, now this was my input file and here if I convert into UTM projection, you can see that it is the 46 zone, here 46 n zone and this is my x coordinate and this is my y coordinate of the UTM map projection for this zone.

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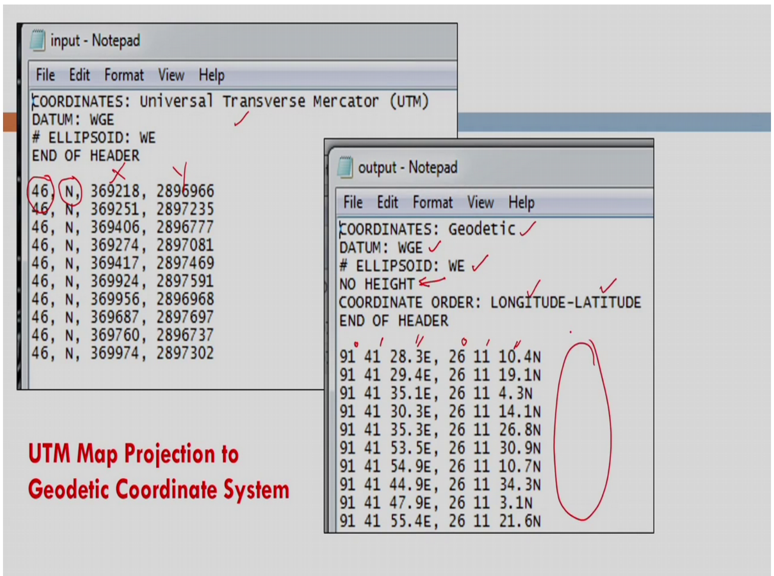

Now, here I am doing the reverse process; that means I am converting my UTM map projection which is given here in the input file with 46 n zones and this is my x and this is my y coordinate. Now, I am converting back and I am getting this which is 21 6 degree latitude 11 second, 10.4 seconds and north and east it is been shown here.

So, I read it again, 91 degree, 41 minute, 28.3 second east, 26 degree, 11 minute, 10.4 second north, that is a latitude and longitude information fine. So, you can try yourself also. Here, if you look at the header file geodetic is a coordinate system, WGS 84 is my datum ellipsoid is also WGS 84, no height you see and then coordinate order is longitude and latitude ok.

Here in the input if you see that universal transverse Mercator which is already a map projection see and WGS 84 coordinate and ellipsoid here, we are not saying that there is no height because we know that map projection system by default is a 2 D projection system, but geodetic can be a 3 D or 2 D and that is a reason in case of geodetic coordinate system, we say whether we have a ellipsoid a height or whether a whether we have do not have the height. In case of a do not we do not have the height, so heights are not specified here in the output.

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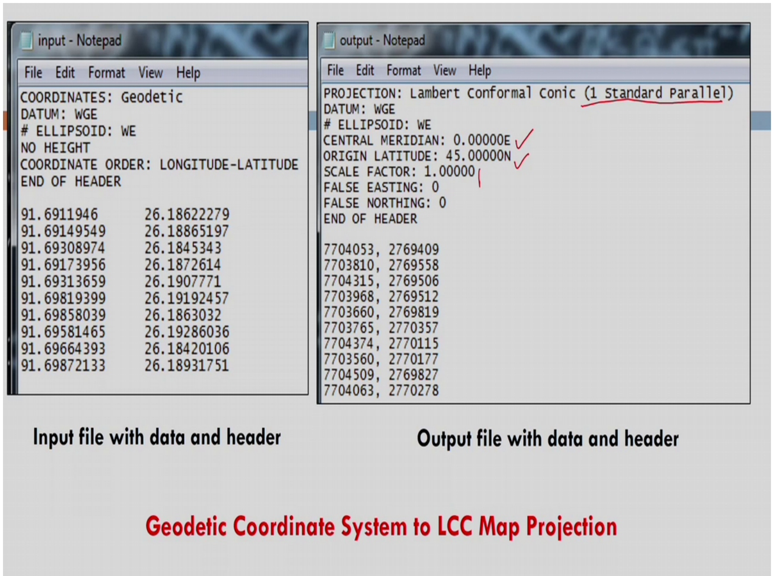

Now, coming to the geodetic coordinate system to LCC map projection, so, what I am doing here is, this is my input file which is already prepared on now I am converting here. In case of LCC, you see it is a one standard parallel that is a tangent system, it is touching the surface of the earth at this standard parallel. So, the central meridian is my this and origin of latitude is this, scale factor and then false easting and false northing.

Since this LCC projection, one standard parallel or 2 standard parallel are user specified. So, we need to specify false easting and false northing. In case of UTM, it has it is own arrangement where UTM has some false easting and some false northing value, especially in the positive like around 5 lakhs and because of that, we will never get any negative coordinate there, you see here.

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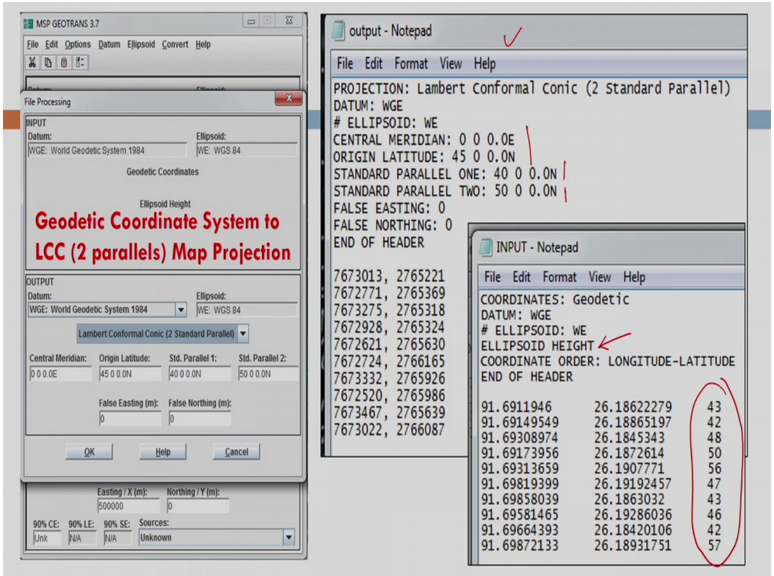

So, geodetic coordinate system to LCC to parallel map projection, ok.

So, you can see this is the interface here and this is my output files which is shown of here and this is a input file you can see here. There is a height information also right and here I am specifying ellipsoidal height. You see the magic in the map projection, you do not get any height because the map projection does not use the height information at all. So, even you specify the height, it is not going to matter for the map projection for this application ok.

Now see here, this is a central meridian of first standard parallel. So, this is some standard parallel 1, standard parallel 2 and again I am specifying false easting and false northing here ok, let us go ahead.

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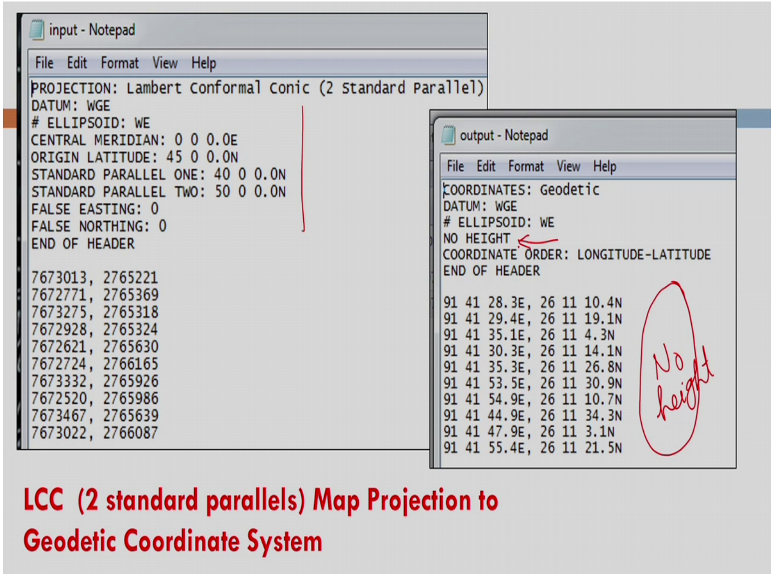

.

And this is back; that means, from LCC 2 standard parallel and map projection to geodetic coordinate system. So, these are the again input information I am providing and I am getting this thing.

If you see here, there is no height and that is been indicated here, no height ok.

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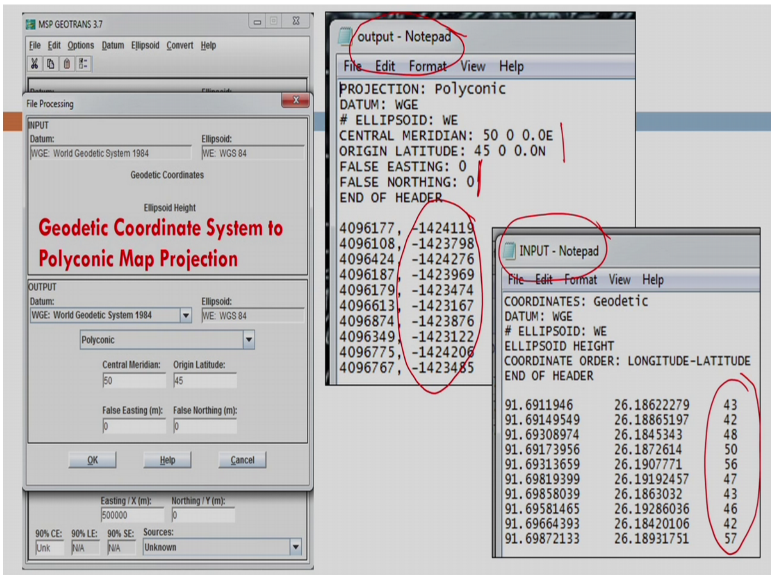

Again, now coming to the polyphonic projection system here, the central meridian and origin of the latitude are there. I am converting the geodetic coordinate system to polyphonic. So, in case of polyphonic this is my output here, you see and this is the input here and again input is we given with the height which is not going to make any sense for this application and see since there is a false easting and false northing are geo, I am getting this negative coordinates. No worries, if you specify false easting and false northing as a positive values; let us say 5 lakh 5 lakh, you will get some positive value always.

So, you have to be careful when we chose some kind of particular application or particular map projection system ok. Then, you also learned how to write the header file and which is pretty easy now ok.

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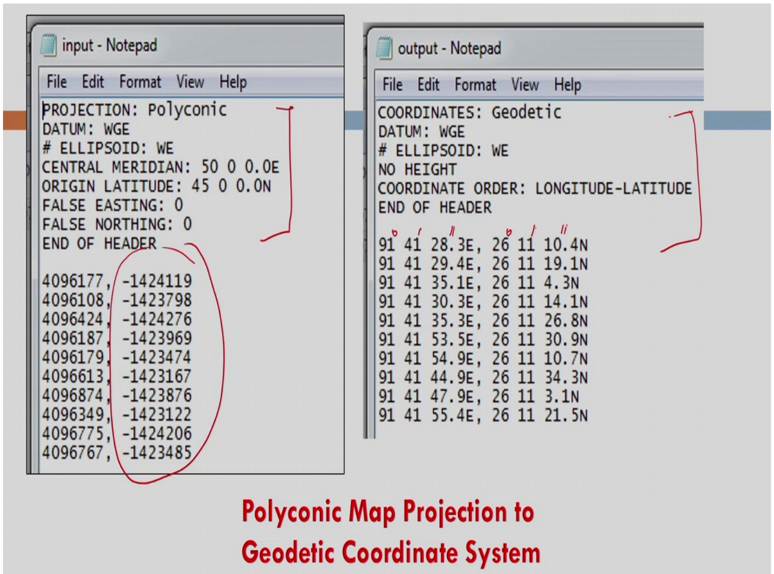

Polyconic Map Projection to Geodetic Coordinate System

Again, back I am doing polyconic map projection to geodetic coordinate system. So, that is a convergence there again I am using with the negative values here and you see that you will get all the correct values, this is degrees, minutes seconds and again this is latitude value degree, minute, seconds, ok.

Here, you can read the header file for output and this is the header file for input, the header information I can say and these are the coordinates, ok.

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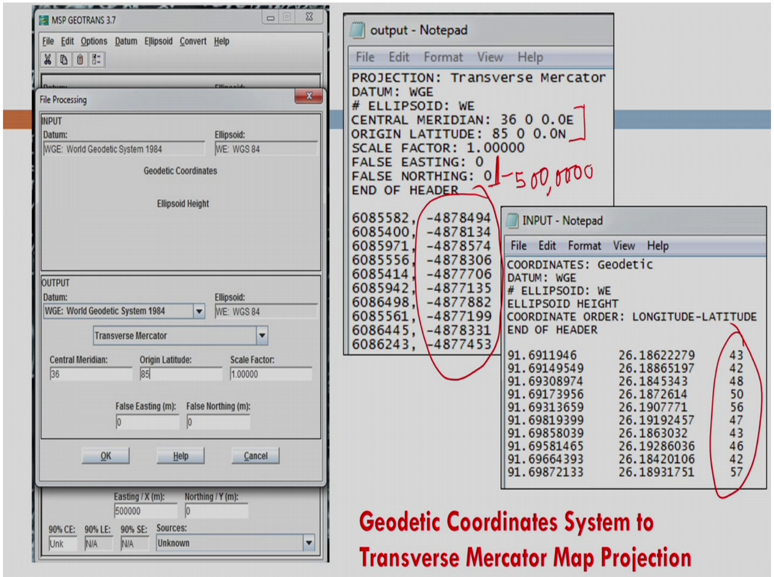

Now, coming to the geodetic coordinate system to transverse Mercator map projection, again remember that transverse Mercator is again user defined and UTM is a specific example of transverse Mercator. So, for that UTM we did not to define anything, but in case of any other projection, we need to define the uses a preferences for the specifications by the user.

So, that is my central meridian information and the output since I am converting from geodetic. Again, height no meaning here and central meridian is there in output origin of latitude is there. So, I get some kind of negative coordinates again here. So, again use some value on the false northing here, let us say if we specify 5 lakhs or maybe 50 lakhs, you will get so, especially 50 lakh, you will get positive coordinates.

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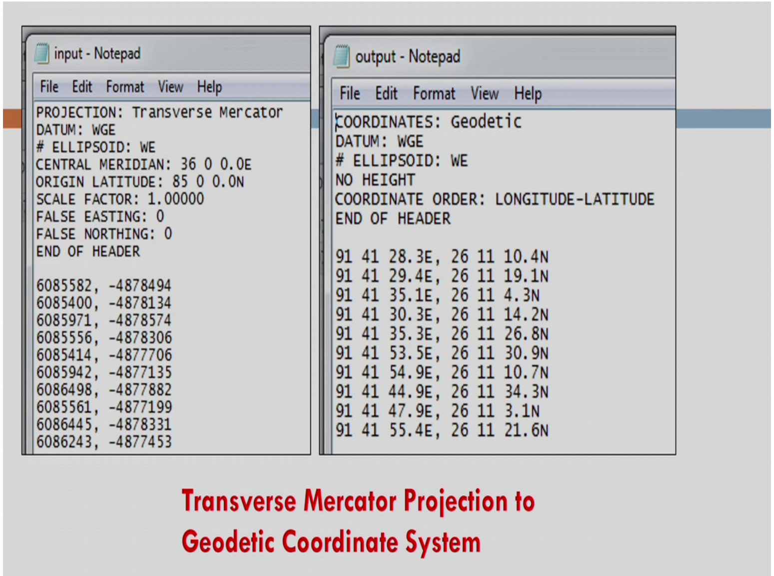

So, again back from transverse Mercator projection to the geodetic coordinates system only. So, only my input is changing and output is I am getting accordingly.

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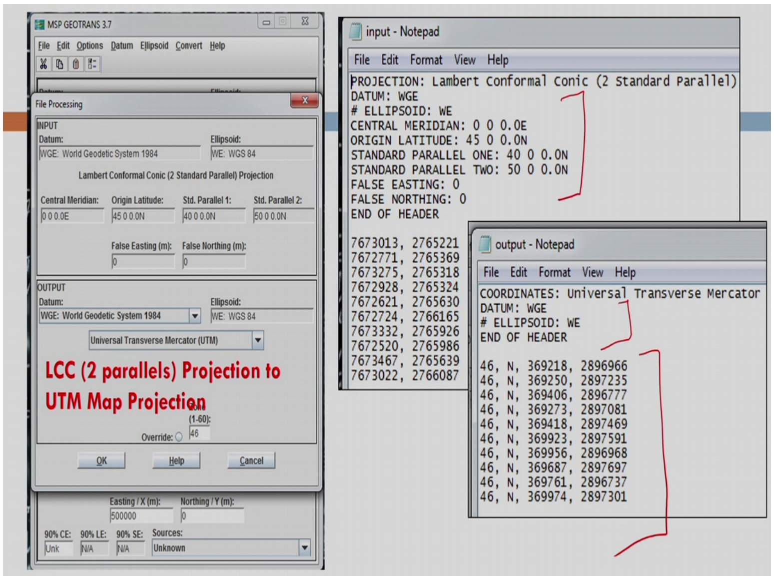

Further now, I am doing the map projection transformation; that means, between one projection to another projection surprisingly here I am not changing my ellipsoid; that means, still I am having the same reference frame. So, within one reference frame, I am using LCC map projection and then I am converting that LCC map projection coordinates into let us say transverse Mercator or UTM or Polyconic projection and so on, fine.

So, what is the process going on. At the backend, you see from the LCC first it is converted to the geodetic coordinate system and then from geodetic coordinate system it is converted to a UTM map projection. So, let us see what is my input. So, input you can see header here, you have already written such kind of header and there we will get the header of this thing, well. You are getting the correct terms, you can match it and you can do it yourself also; that means, you use these coordinates this information and repeat the exercise for yourself.

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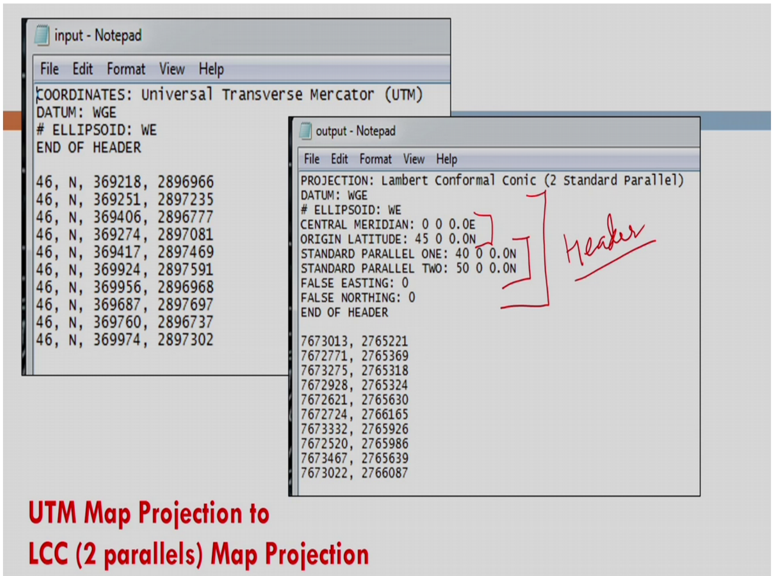

Further, you see the UTM map projection to LCC 2 parallel map projections we are doing here ok. So now, we are given the information and automatically in the output this header will be created, but you need this specify your own information where you want to create this standard parallel and where you want to put your central meridian and origin of the latitudes for LCC map projection to standard parallel.

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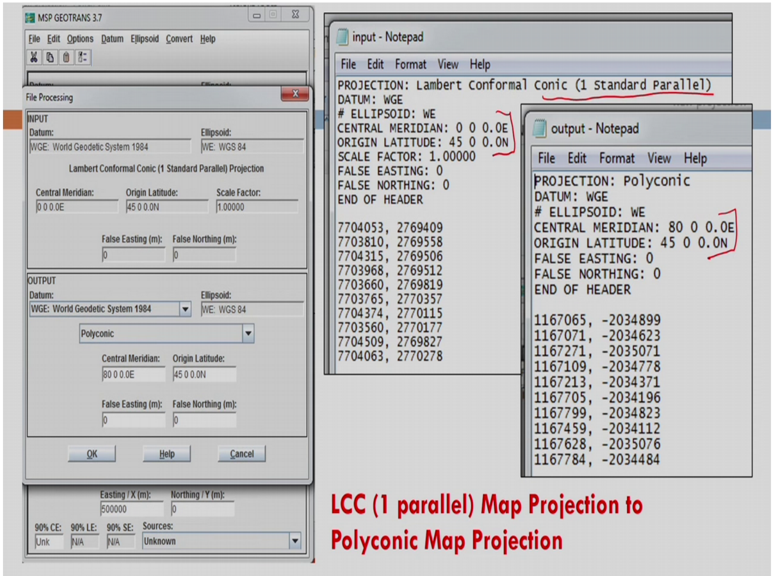

Going ahead, now I am doing the same example for LCC, one parallel map projection to Polyconic, ok.

So, well I have already shown one example. Now, I am putting that another example there only because of one standard parallel, we have different information slightly different information, we have information only for a one standard parallel. So, we have output here, so according to the polyconic map projection here, right.

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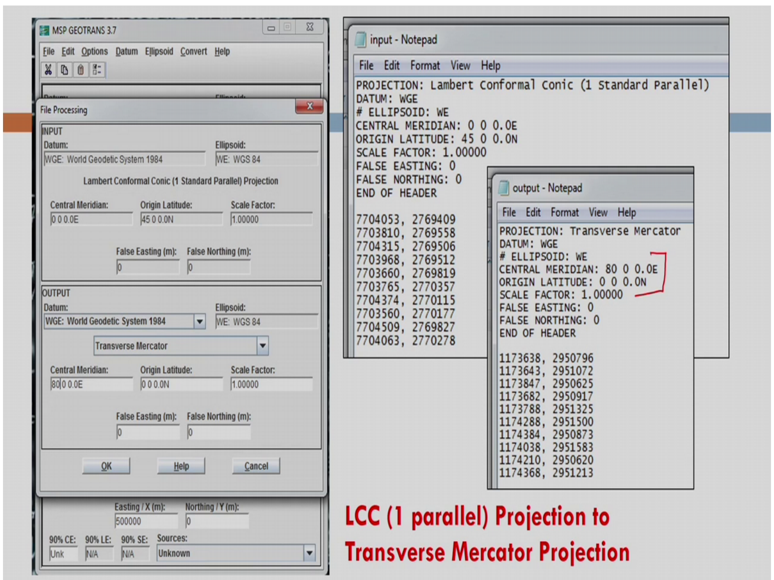

Going ahead with LCC map projection to transverse Mercator, here when you specify in a output that transverse Mercator, you need to specify this information, where do you want to put your LCC, the transverse Mercator origin and so on.

So, accordingly this application will do transformation for you.

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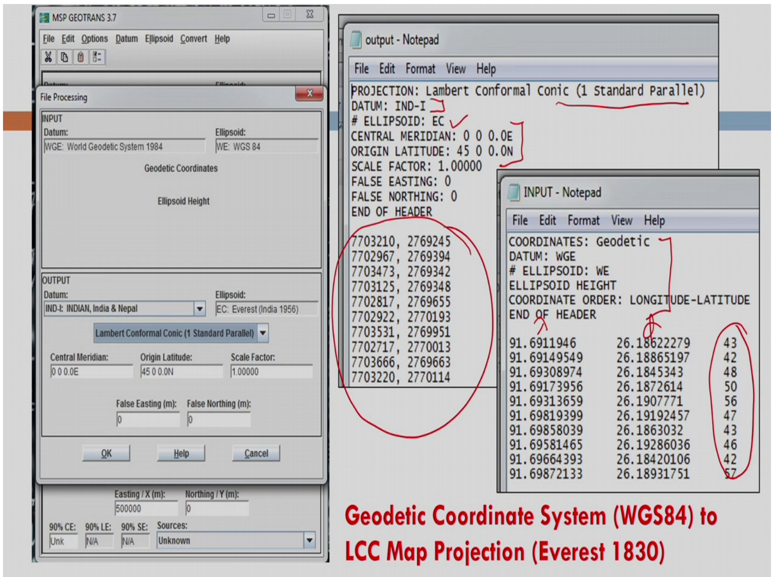

Now, coming to the map projection with datum transformation; so, let us see there is a geodetic coordinate system right and it is being specified in WGS 84 and I am trying to convert into the LCC map projection of Everest 1830, fine. So, we see that input file is there here input and so, I am showing that is this is the longitude information lambda, this is my five information and this is the height information which is of no use.

But now I am going to going to convert this data into the LCC map projection with one standard parallel and datum is Indian, that is Everest 1830, ellipsoid is Everest 1830 and this is a information I have specified on the Everest ellipsoid not on the WGS 84 ellipsoid. So, you have this information with central meridian and origin latitude; with this information if I convert, I will get this kind of a information, here that is my output.

So, now we can specify this information. Again I am doing the same thing back ok, now LCC map projection Everest 1830 to UTM map projection fine. We are doing all this possibilities, we are trying to cover, but remember generally we have LCC map projection for the Everest ellipsoid; that means, UTM projection can be defined for the

Everest ellipsoid, but LCC map projection is not preferred for WGS 84 ellipsoid. So, if you just specify this information again, you will get this kind of a output and this is the interface on the left hand side I am showing.

Now, this it is a reverse one; that means I am using UTM map projection, for WGS 84 in input and I am trying to convert that coordinate in LCC map projection with Everest ellipsoid.

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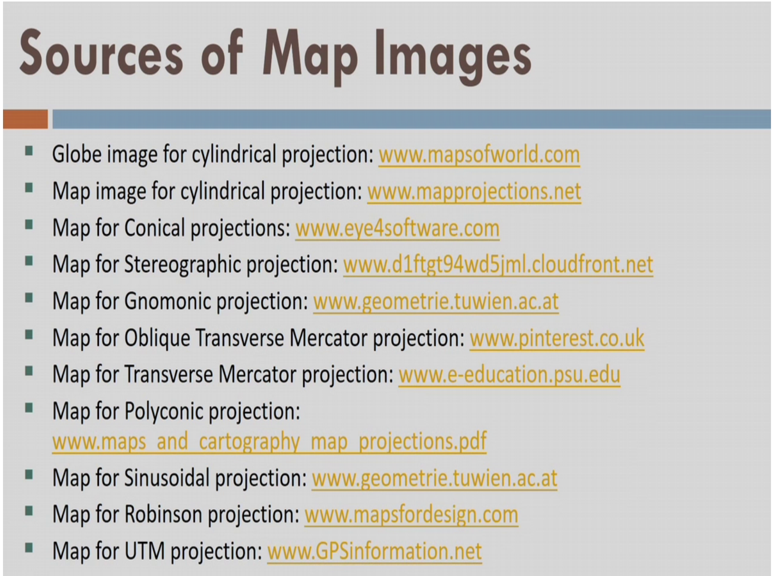

So, these are the sources of the map. So, with this I can say that now you are able to do all the map projection, you can or you are also able to do coordinate transformation, you are also able to do map datum transformation with either reference system or with map projection.

So, here we finish our this module on reference system, coordinate system and map projections. In the next module, we will go for astronomy and time. Till then, bye.

Thank you for attentively listening.