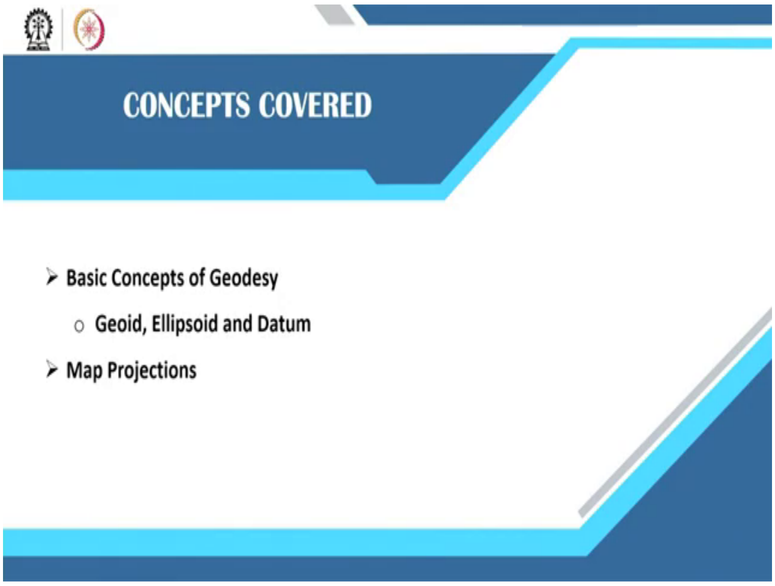
Geo Spatial Analysis in Urban Planning
Prof. Saikat Kumar Paul
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur

Module - 01
Introduction to Geographic Information System and Geographic Distribution
Lecture - 02
Introduction to Corrdinate System and Geographic Projections

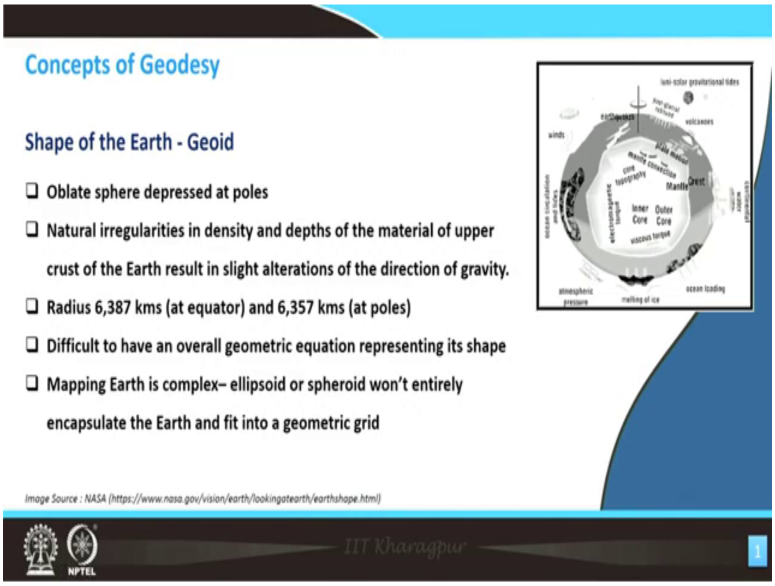
Welcome to the course on Geospatial Analysis in Urban Planning. This is the NPTEL Online Certification Course and we are I mean in the 2nd lecture of module 1 which is Introduction to Geographic Information Systems and Geographic Distribution. And we would be dealing with geodesy the concepts of geodesy, geographic projection and the coordinate system in this particular lecture.

(Refer Slide Time: 00:41)



So, we would be talking about the basic concepts of geodesy; geoid, what is an ellipsoid, what is the datum and then we will see how what are the different types of map projections and how can it be used in gis.

(Refer Slide Time: 01:02)

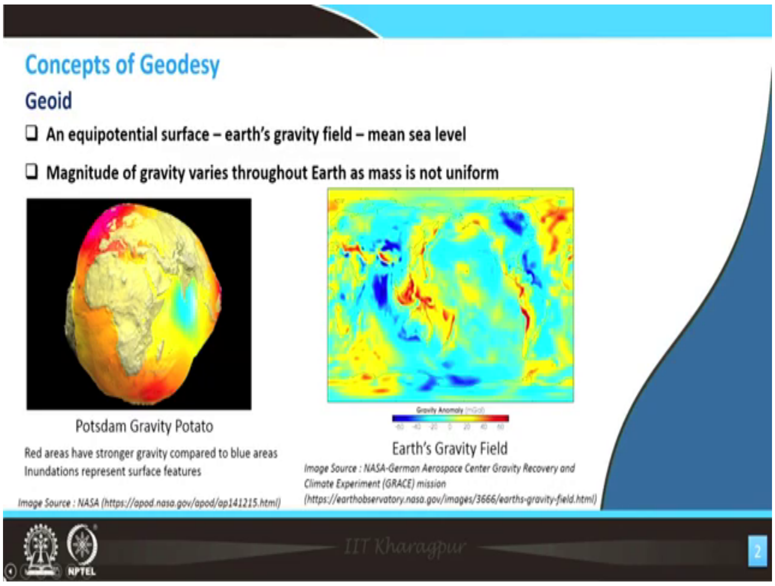


Now, if we see the shape of the earth, we can we generally call it as a geoid. It is basically oblate sphere having depression at the pole. So, it looks more like an orange basically I mean we just depressed at the pole and at the equator it is I mean inflated. I mean this shape results because of difference in the density of the materials, materials of the earth crust upper crust basically and it would I mean have an impact on the direction and the I mean intensity of the gravity across the different points on earth surface.

We know that earth surface at the equator roughly I mean is about 6387 kilometers whereas, at the poles it is slightly less which is about 6357 kilometers. So, I mean the biggest challenge for us is to represent this particular surface as a geometric surface.

So, I mean mapping or modeling this surface becomes a very complex task and it is really difficult to have a equation of a 3D solid which would encapsulate this earth surface in each of the points. So, what happens is we try to create regional I mean fit is which regional models which would fit the I mean different zones of the earth.

(Refer Slide Time: 02:54)



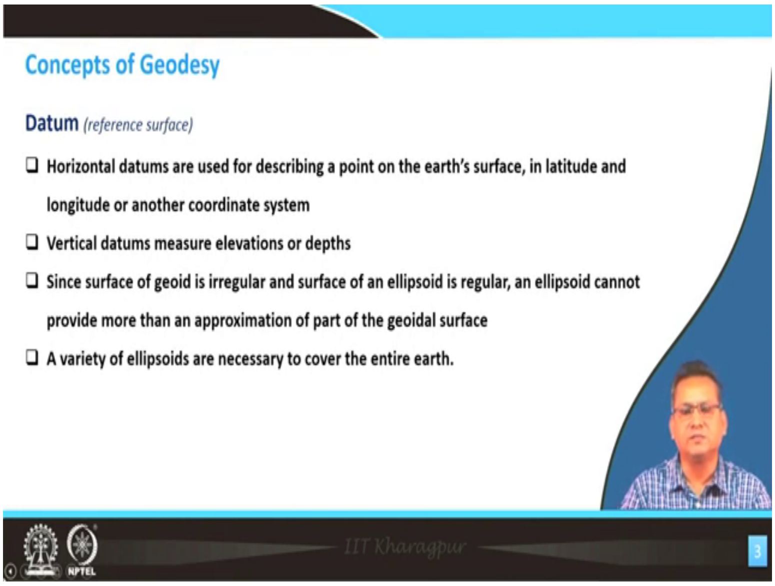
So, if we look into the concepts of geodesy so, this equipotential surface is basically a geoid and it I mean is a representative surface of the earth's gravity field and mean sea level which is the meniscus of the earths I means ocean surface across the earth is taken as I mean datum or a reference surface and this is taken as a in the global context to measure the elevation of given points.

So, this equipotential surface is generally measure is used to measure the precise surface elevations on the earth. Now, there is another term which is known as orthometric height which is height above an imaginary surface which we have just now referred to as geoid which is determined by the earth's gravity and approximated by the mean sea level.

Now this magnitude of earth's gravity varies as the mass is not uniform and we have already I mean talked about it in our earlier slide. This is because that gravitational strength by elevation data. I mean if we portray it I mean if you refer to the first image, we can see that it looks like I mean deformed shape 3 dimensional shape which represents which looks like a potato.

So, this is this image was generally termed as Potsdam gravity potato because this gravity data was analyzed in Potsdam in Germany. Now this gravity anomalies are often due to unusual concentrations of mass in a given region and this presence of ocean trenches or depression of landmass caused by presence of glaciers millennia ago can cause negative gravity anomaly.

(Refer Slide Time: 05:5)

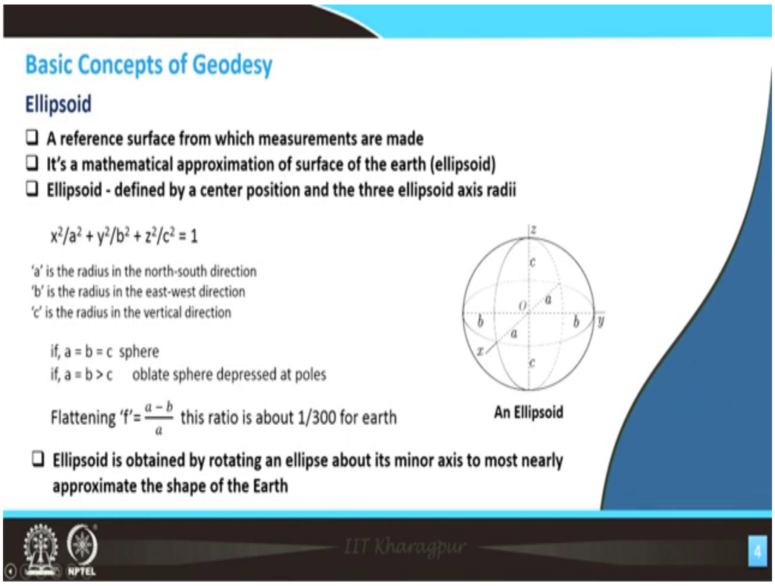


Now, if we go to the horizontal datums, we have horizontal references or vertical references from which we measure the horizontal points or the vertical points. So, generally the horizontal datums are the latitudes and longitudes or other coordinate systems which are measured in unit is of distances.

We also have vertical datums basically it is reference to the geoid which measures the elevations or the depths with respect to that particular surface. Now, your we have seen that the geoid is an irregular surface. So, to approximate it as a geometric surface what we do is, we create a ellipsoidal surface which is basically a surface resulting when we rotate an ellipse about it is semi minor axis.

Now there are a variety of ellipsoids which has been I mean formulated for covering the entire earth because I mean it is so deformed that it is difficult for us to have one ellipsoid covering the entire earth surface.

(Refer Slide Time: 06:22)



Now, ellipsoid is basically a reference surface which from which we can measure different heights or distances along x or y and heights in the z mention. It is a mathematical approximation of the surface of the earth and we said it is a surface of revolution. So, ellipsoid can be defined by three axis and in this case we have termed the radius; in this equation the radiuses are a, b and c and it is represented by this particular equation.

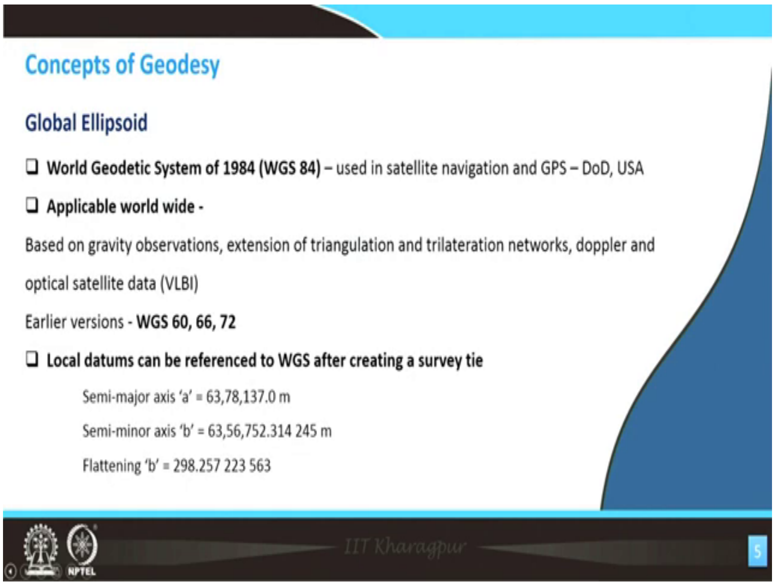
So, it is a surface of revolution basically created as a result of revolution. This equation is x square by a square plus y square by b square plus z square by c square which equals 1. Now if a and b and c are equal, then the resulting geometry would be that of a sphere.

If a and b are same, but it is greater than b then what happens is if the resulting geometry would be that of an oblate sphere and it would be depressed at pole. So, we coin a term which is known as flattening. It is the difference of a and b the two different axis along the x and the y divided by a for earth this ratio basically comes to about 1 by 300.

Now, this reference ellipsoid is the mathematically defined surface which approximates the geoid and this is a quadratic surface as we have seen it in the equation. The GPS uses height above the reference ellipsoid that approximates the earth surface.

The traditional orthometric height is the height above an imaginary surface called the geoid which is determined by the earth's gravity and approximated by mean sea level. Now, geoid height is the ellipsoidal height from an ellipsoidal datum to the geoid.

(Refer Slide Time: 08:42)



Talking about global ellipsoidal systems, we have created different ellipsoidal systems in global context or in local context. So, let us see the global ellipsoidal system which is known as the world geodetic system abbreviated as WGS84 and is generally used for satellite navigation extensively in the GPS.

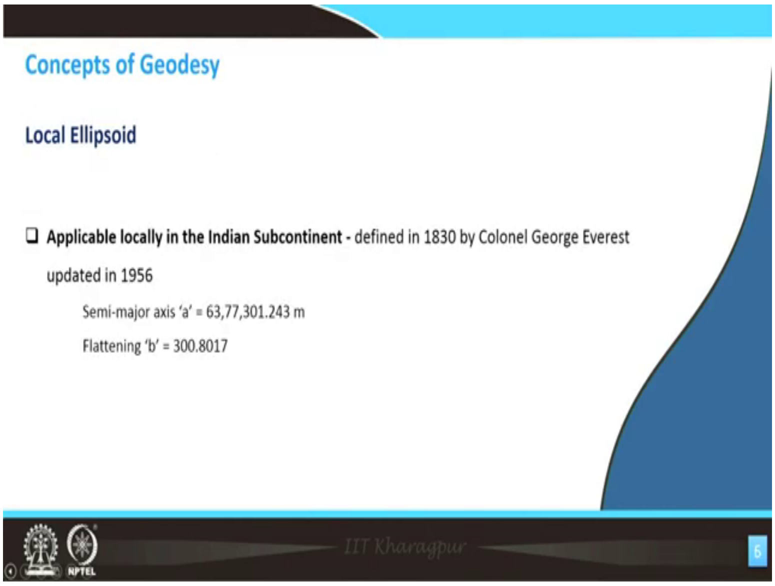
So, all the GPS readings that you take from your handheld GPS or I mean dual frequency GPS or your mobile GPS readings are based on this ellipsoidal system that is WGS 84. This was given by the Department of Defense of US and this is applicable globally there were earlier versions in 60, 66 and 72.

So, this the earlier version of the that is WGS72 did not I mean provide sufficient data for the accuracy in terms of resolution of the distances or height. So, the GRS parameters with available Doppler, satellite laser ranging and very long baseline interference interferometry observations constituted a significant new information. The new source of data had become available from the satellite radar altimetry as well.

So, the advanced least square method called collocation which allowed consistent combination solution from different types of measurement all related to earth's gravity field that is geoid, gravity anomalies, deflection, dynamic doppler etcetera were used in the subsequent correction to formulate the WGS 84 system over the preceding forms I mean the WGS 60, 66 and 72. So, this was corrected to a in the WGS 84 reference system.

So, it is geocentric and globally consistent this particular system within plus minus 1 meters. So, the current geodetic realization of the geocentric reference system family that is the International Terrestrial Reference System ITRS is maintained by IERS are consistent even at few centimeter levels and meter level consistent with WGS 84.

(Refer Slide Time: 11:21)



Now, if we look at some of the local ellipsoids. There are few ellipsoids which are applicable in different parts of the world like we have the Australian ellipsoid of 1965 which is used extensively in Australia, Krasovsky of 1940 which is used in Soviet Union, we have Clarke which is Clarke 1980 and 1980 1860 and 1860 1880 which is used in most of the Africa, France, Northern America and Philippines.

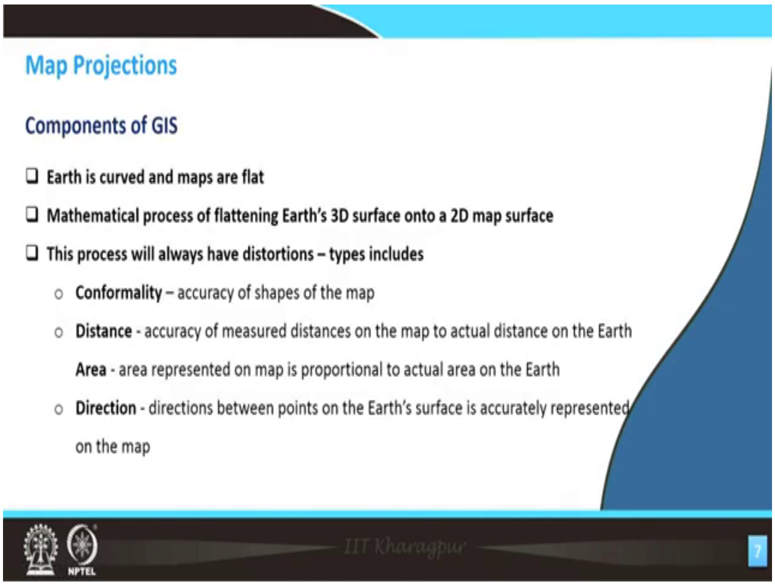
We use the Erie ellipsoid for great Britain, Bessel is used in Central Europe, Chile and Indonesia and the Everest ellipsoid is used in India, Burma, Pakistan, Afghanistan, Thailand and predominantly the Indian subcontinent. So, this Everest or the Indian system has been used in India for more than 150 years.

This Everest ellipsoid is a mathematical spheroid roughly representing the shape of Indian subcontinent and has been assumed by the surface of India and all measurements are related to this particular spheroid. It was defined in 1830 by Colonel, it is a George Everest and it was updated in 1956.

The reference datum fixed by the survey of India is located near Kalyanpur in Madhya Pradesh. The Indian spheroid has been marginally modified on a number of occasions so that the parameters assumed for this spheroid have been refined slightly from time to time. So, the changes were made in the year 1930. The first version came in 1830. The revisions were done in 1930 and 1956. The it is important to know that the center of Everest spheroid does not concede with the center of the earth.

So, the flattening parameter for the Everest ellipsoid is about 300.8017 wherein in the earlier case we have seen for the WGS 84, the flattening parameter was about 298.257 meters.

(Refer Slide Time: 14:00)



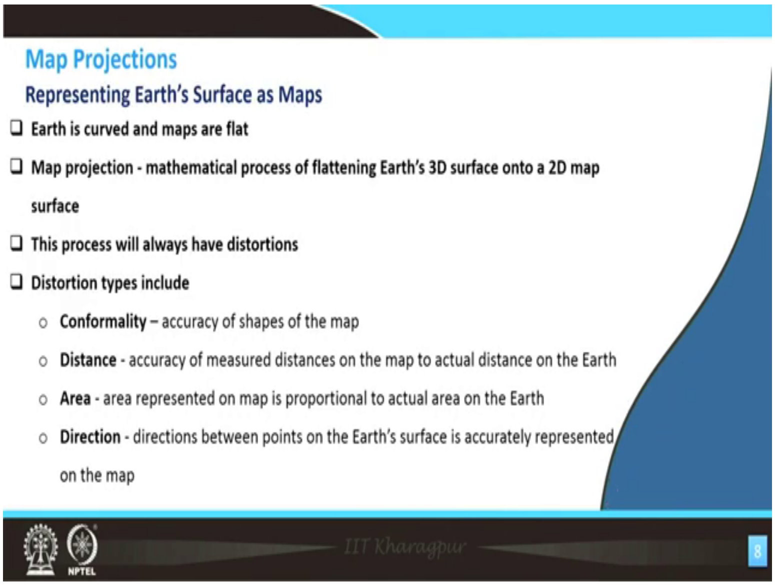
Going to the components of the GIS I mean when we are talking about map projections our earth as we have seen is curved and it is very difficult for us to create a map out of this curved surface that is to represent this map, I means this curved surface as a flat surface.

So, basically the projection a map projection is the mathematical process by which we flatten the earths surface onto a 2 dimensional surface. So, this process is very difficult I mean we cannot always have a proper representation of a 3D surface on a 2D surface. So, there would be errors or distortions involved and the types of this distortions are mostly four types; one is conformality in terms of the nature of the shape of the map whether the dispreserved or not.

Then we have accuracy in terms of measurement of distance I mean if we scale the particular map whether that is accurate when we corresponded to the measurements on the earth surface. The next is the area whether the area of the map is proportional or to the actual area that is measure on the ground or earth and the directions.

So, I mean whether the directions are measured properly along the I mean points on the map surface and it basically correlates well with appropriate measurement on the ground.

(Refer Slide Time: 15:37)



Projecting the three 3D surface of earth on a piece of paper can be imagined similar to a problem of arranging orange peel on a flat surface. Now the map projection is the mathematical approach of projecting earths 3D surface on a 2D map surface and we have seen that it will result in distortions.

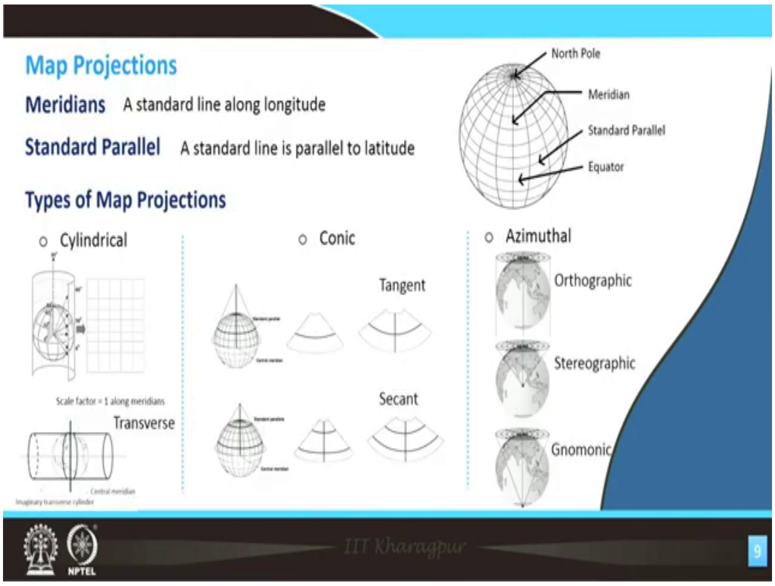
So, the first that we had discussed conformality that is the accuracy of the shape is most common and most important projections are conformal or orthomorphic normally. The relative local angles about every point on the map are preserved. Since local angles are correct meridians intersect parallels at right angles and on a conformal projection, a local scale in every direction around any one point is constant. Most large scale maps throughout the world are now prepared on a conformal projection.

Now, talking about distance I mean measuring the accuracy of the distances measured on the map to the actual measurements on the earth surface, I mean talking about it no map projection actually shows the scale correctly throughout the map. But there are usually one or more lines on the map along which is scale would remain true.

Some projections show that true scale along meridians are known as equidistant projections. The I mean when we have area specific distortions the map would cover exactly the same area of the actual earth, I mean the projections which would reduce the amount of distortions in terms of area.

So, the common terms used for equal area projections are equivalent homolographic or homalographic and no map can be both equal area as well as conformal. Talking about preserving the direction conformal maps gives the relative location directions correctly at any given points. The azimuths of all points on the map are shown correctly with respect to the center and are known as azimuthal projection.

(Refer Slide Time: 18:19)



So, I mean talking about the representation of earth as a ellipsoid, we have we define two lines. First is the meridian which is a standard line along the latitude. So, I mean before we get to learn about the map projections it is important for us to know these concepts.

So, this meridians of longitude are formed with the series of imaginary lines, they all intersect both at the north and the South Pole and crisscross each parallel of latitude at right angles, but striking the equator at various points. Now we have the standard parallel which is shown in the image. So, it is when parallels of latitude are formed by circles surrounding the earth and in planes parallel with that of the equator.

So, if we are to represent a surface I mean planar surface representing that of a 3D surface, we can I mean circumscribe a sheaf of paper in either a cylindrical way as has been shown or in or to make a cone and it would touch the surface of the earth either as a tangent or it could be in a secant form wherein it would intersect the surface of the earth at two points or we can also put it in a orthographic mode azimuthal mode wherein we put the sheaf of paper and the lines are projected.

So, let us see the first one that is the cylindrical projection. So, cylindrical projection mosts of the cylindrical projections are of two types; it is either vertical, it could be oblique as well or it could be transverse. So, the most popular projection which is used globally is the transverse cylindrical projection.

Now, this cylindrical projections they are conformal in nature and they have central meridian and each meridian is 90 degree from the central meridian and equators are straight lines. The other meridians are parallel and they are complex curves as you can see that when we expand this we I mean cut this sheaf of paper which is basically super scribing this globe and open it up as a map, you can see the standard parallels and basically the meridians.

So, I mean it has been shown for each of these cases in the particular images. So, the scale in this particular case is true along the central meridian or along two straight lines equidistant from and parallel to the central meridian. It is used for extensively for making quadrangle maps ranging with scales ranging from 1 is to 24000 to 1 is to 2000 2,50,000.

Now, talking about the conic projection, we have seen that the cone could be superimposed on the surface of the earth in two ways either tangentially or I mean having secants. The parallels in this case are unequally spaced arcs of concentric circles and it is more closely spaced at the north and south edges of the map. The meridians are equally spaced radii of the same circles cutting parallels at right angle. There is no distortion in scale or shape along the two standard parallels.

So, the scale would be I mean true and the shape is also preserved; normally or along just one of these standard parallels. The poles are arcs of the circles. These type of projections specially the conic projections I mean an example is the polyconic projection or the Lambert conformal conic projection. So, these are used for equal area maps of regions having predominantly east west expands.

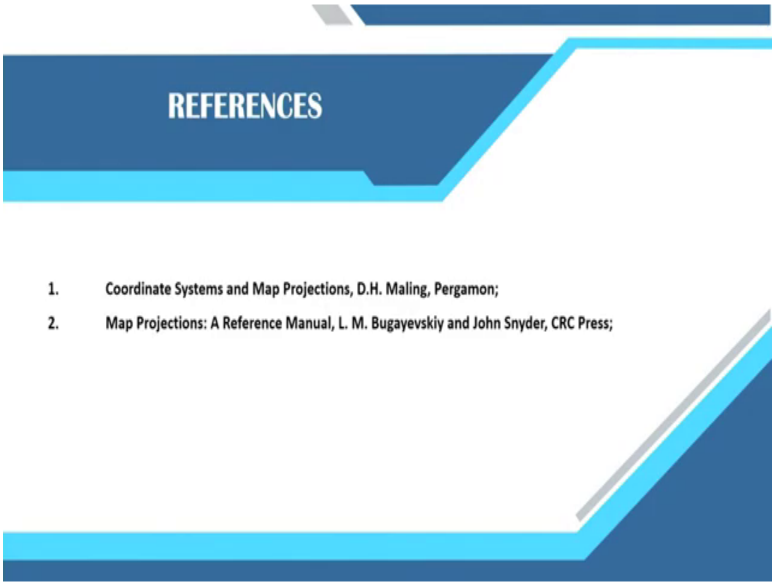
So, I mean talking about the conformal projection, I mean we had earlier talked about the conformal projection these are I mean they have a constant scale along the equator and they are generally referred to as Mercator projection and the constant scale along the meridian in case of your transverse Mercator projection. For the equal area we have the third type which is the azimuthal projection or the equal area projection.

So, in this type we have the standard without interruption which is known as Hammer projection or the Mollweide (Refer Time: 23:41) 4 or the version 6 Macbride Thomas variations, Boggs Eumorphic or sinusoidal projection. So, these azimuthal equidistant projection are centered on pole and these types of projections are basically polar azimuthal equidistant projection or centered on a city which is oblique azimuthal equidistant projection.

So, the azimuthal projection can be three types; I mean we can place the paper in a orthographic mode and we can project the standard parallels and the meridians in a orthographic mode. The second the way of projecting the standard meridians and the parallels could be in a stereographic format or it could also be done in a gnomonic format gnomonic way as shown in the particular image.

So, with this we conclude this particular I mean lecture and in this particular lecture, we have covered the basic concepts of geodesy. We have defined what is a geoid, what is a ellipsoid, what are ellipsoidal heights, what are geoidal heights. We have also talked about the different types of projections and what are the types of errors that would be introduced due to projecting a 3 dimensional surface on a 2 dimensional paper plane when we are creating maps.

(Refer Slide Time: 25:14)



So, we have a book some reference books which you can read further to I mean learn more about this particular topic. So, we have the first book by Maling it is from the Pergamon Press. It is titled Coordinate Systems and Map Projections and the second book is by Bugayevskiy and John Snyder. It is from CRC Press, book title Map Projection: A Reference Manual.

Thanks.