# MAP PROJECTION

## Unit: II

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## MAP PROJECTION

### 1.1. Introduction:

Projection or Projected coordinate systems are used to locate objects on a flat, 2D surface. The latitude and longitude coordinates are converted into x and y coordinates on the flat projection. The plane is marked at intervals by equally spaced coordinate lines, called the map grid. Mapping onto a 2D plane means transforming geographic coordinates ($\phi$, $\lambda$) into a set of Cartesians (x, y) coordinates that represent positions on the map plane (Figure 1.1). Map projections are projected coordinate, used to display the earth on a flat plane. In the projected coordinate system, locations are identified by (X, Y) coordinates on a grid, with the origin at the centre of the grid.

For the given two numerical coordinates x and y of point P, one can precisely specify any location P on the map. In the projected coordinate system, locations are identified by (X, Y) coordinates on a grid. Normally, the coordinates x = 0 and y = 0 are given to the origin at the centre of the grid. However, sometimes large positive values are added to the origin coordinates. This is to avoid negative values for the x and y coordinates in case the origin of the coordinate system is located inside the area of interest. The point which then has the coordinates x = 0 and y = 0 is called the false origin.

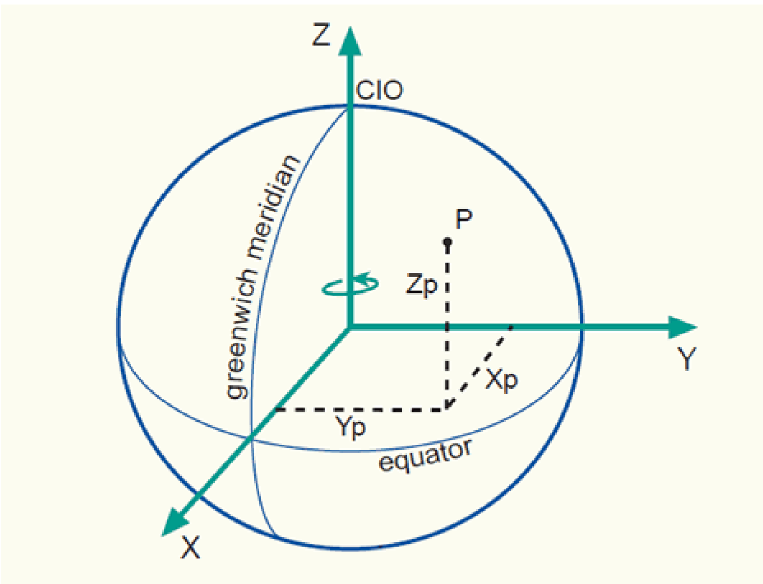


Figure 1.1: An illustration of the geocentric coordinate system

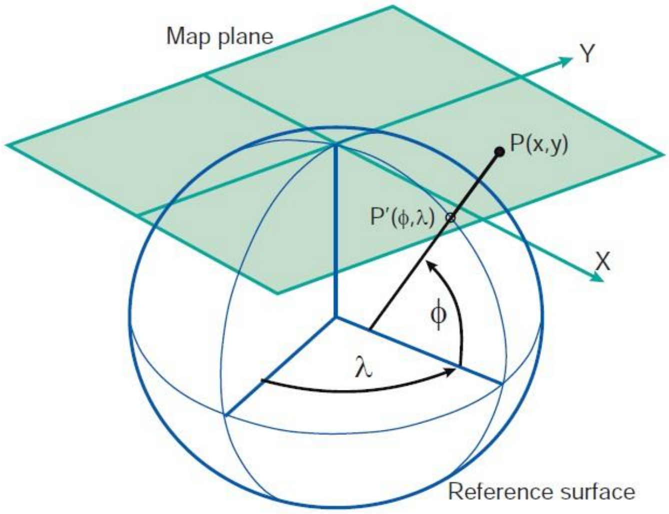


Figure:1.2. Geographic coordinates (ϕ, λ) projected onto the 2D mapping plane with 2D Cartesian coordinates (x, y)

## 1.2. Types of projection

There is no universal criterion used to classify projections. However, this subsection briefly discusses the types of projection as follows.

### 1.2.1. Types of projection based on developable surface

One method to classify map projection types is by considering the surface at which the map is developed. A developable surface is the one which can be flattened and receive projected lines or drawn directly from an assumed globe. There are three types/ classes of this kind commonly used in GIS. They are cylindrical, conic, and azimuthal/ planar projections.

#### 1.2.1.1. Cylindrical projection:

Cylindrical projection is usually placing the earth inside a cylinder with the equator tangent or secant to the inside of the cylinder. Lines and points on the spherical grid can be transferred to this cylinder, which is then unrolled into a flat map. Distortions may appear in area, angle, distance or direction. There are three types of cylindrical projection: normal, transverse, and oblique.

- ✓ In a normal projection, the main orientation of the projection surface is parallel to the Earth's axis. The equator is the standard line; hence this projection has no distortion on the equator and low distortion nearby, and suitable for tropical countries.
- ✓ Transverse projection has its main orientation perpendicular to the Earth's axis. It gives

maps with no distortion on the central meridian and low distortion nearby, and suitable for countries at any latitude.

- ✓ Oblique projections are all other, non-parallel and non-perpendicular. Transverse and oblique aspects of many projections can be used for most parts of the world.

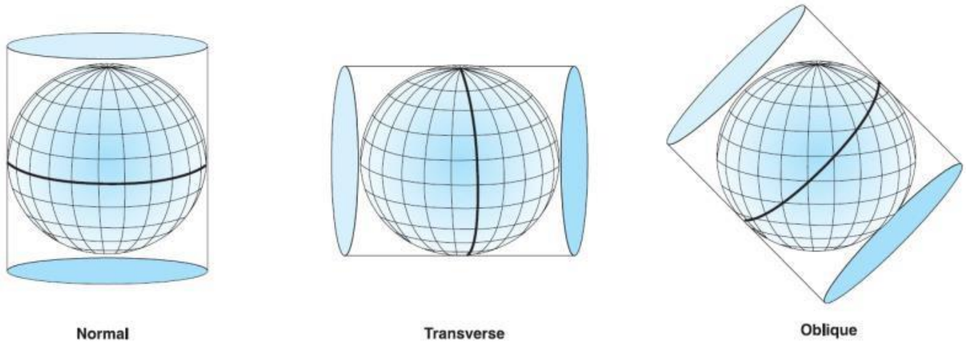


Figure:1.3 normal, transverse, and an oblique cylindrical projection

**1.2.1.2. Conic projections:**

Conic projections resulted from projecting a spherical surface onto a cone by transferring of parallels, meridians and points from the generating globe grid to a cone enveloped around the globe. Then, the cone is unrolled into a flat plane. In the normal aspect, the axis of the cone coincides with the axis of the sphere. This aspect yields either straight or curved meridians that converge on the near pole and parallels are arcs of circles. In this projection, points are projected radially onto the cone. The simplest conic projection is tangent to the globe along a line of latitude, along which there is no distortion. This line is called the standard parallel. In the secant case, the cone intersects the sphere along two parallels on a globe. This reduces distortion (e.g. Lambert conformal conic projection).

Distortion increases away from the standard parallel. Thus, cutting off the top of the cone produces a more accurate projection. This is not used for Polar Regions of the projected data. Instead, conic projections, simple or secant, are best for mapping earth areas having great east-west (longitude) extent than north south - mid-latitude zones. However, for small areas, distortion is minimal.

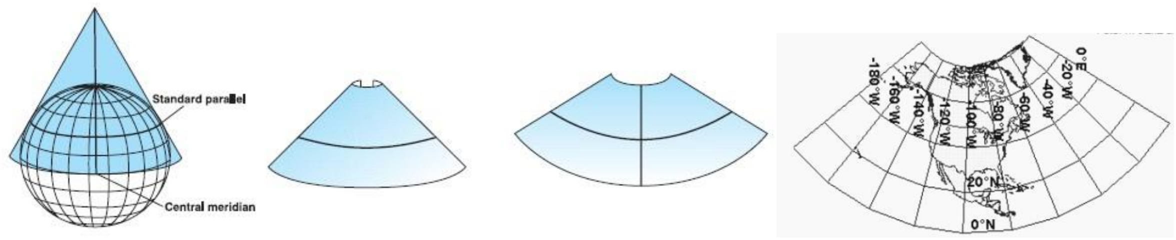


Figure:1.4 Conic projection

### 1.2.1.3. Azimuthal/l or planar projections:

Azimuthal projections project map data onto a flat surface touching the globe by transferring of parallels, meridians, and points from the generating globe to a plane sheet of paper enveloped around the globe. It is made upon a plane tangent (or secant) to the reference surface (the globe). The point of contact may be the North Pole, the South Pole, a point on the equator, or any point in between. Tangency at the poles is a normal/polar aspect. At the equator, it is an equatorial aspect. At middle latitude, it is oblique aspect.

In the polar cases, all meridians radiate out from the pole at their correct angular distance apart; and are straight lines converging at the pole. Parallels are concentric circles having the pole as their centres. All lines drawn to the centre are great circles, as is also for equatorial and oblique aspects. Normally, only one hemisphere is shown on these projections. As is for all projections, distortions increase with distance from either the standard point or the standard line. All azimuthal projections possess the property of maintaining true directions from the centre of the map on the plane map or on the projection. An example is the Universal Polar Stereographic coordinate system.

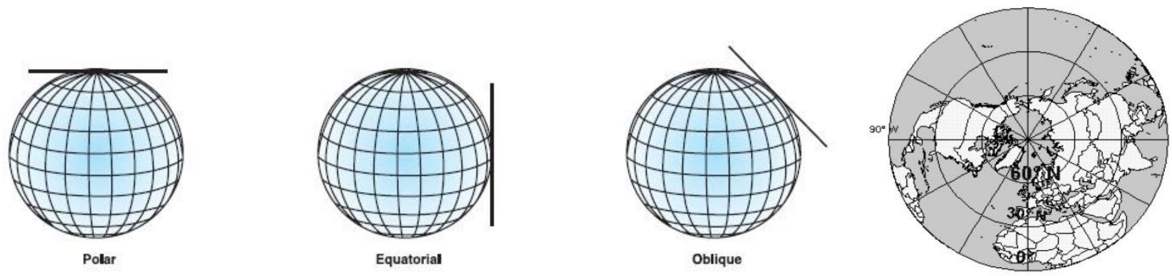


Figure:1.5 Azimuthal or planar projections

### 1.2.2. Projection types based on the characteristics of the resultant projected maps:

Map projections are designed for specific purposes. One map projection might be used for large-scale data in a limited area, while another is used for a small-scale map of the world. So far, we have not specified how the Earth's reference surface is projected onto the plane, cone or cylinder. How this is done determines which kind of distortion properties the map will have compared to the original curved reference surface. The distortion properties of map are typically classified according to what is not distorted on the map.

#### 1.2.2.1. Conformal (Orthomorphic) projections:

When the scale of a map at any point on the map is the same in any direction on the earth, the projection is conformal. In a conformal (orthomorphic) map projection, the angles between lines in the map are identical to the angles between the original lines on the curved reference surface. This means that angles (with short sides) and shapes (of small areas) are shown correctly on the map. Meridians (lines of longitude) and parallels (lines of latitude) intersect at right angles. However, the actual amount of stretching varies from latitude to latitude. The area enclosed by conformal projections preserve local shape, and angles (e.g. Mercator projection). As the region becomes larger, they show considerable area distortions. Area distortions are significant towards the Polar Regions. For example, Greenland appears to be larger but is only one-eighth the size of South America. Maps of smaller regions are not distorted. Maps used for the measurement of angles, such as topographic maps, often make use of a conformal map projection. No map projection can preserve shapes of larger regions.

#### 1.2.2.2. Equal area projections:

When a map portrays areas over the entire map have the same proportional relationship to the areas on the Earth that they represent, the map is an equal-area map. In an equal-area (equivalent) map projection the areas in the map are identical to the areas on the curved reference surface (taking into account the map scale), which means that areas are represented correctly on the map. Equal area projections preserve the area of displayed features; and other properties—shape, angle, and scale—are distorted. Examples are cylindrical equal area, zenithally equal area, and Albert's equal area conic projection.  This projection is not suitable for areas, which extend to higher latitudes. For example, Africa can be shown on this projection suitably as the equator almost cuts it into two halves. As the region becomes larger, it shows considerable distortions of angles and shapes.  Maps which are to be used for measuring areas (e.g. distribution maps) often make use of an equal-area map projection.

#### 1.2.2.3. Equidistant projections:

When a map portrays distances from the centre of the projection to any other place on the map. In an equidistant map projection, Distances between two points on parallels are correctly shown on the curved reference surface or the globe does (taking into account the map scale). Similarly, the distances along the meridians are also truly drawn and spaced correctly on these projections. That means, the length of the line on a map is the same length (at map scale) as the same line on the globe. Hence, distances are true to scale. Examples for equidistant projections are Conic equidistant and cylindrical projections. Maps which require correct distances measured from the centre of the map to any point (e.g. air-route maps) or maps which require reasonable area and angle distortions (several thematic maps) often make use of an equidistant map projection. No projection is equidistant to and from all points on a map.

## 1.3. Commonly used map projections:

### 1.3.1. Mercator projection:

Mercator projection is a conformal cylindrical map projection. At every point location, the east-west scale is the same as the north-south scale, making the projection conformal. Being a conformal projection, angles are preserved around all locations. Mercator projection distorts the size of objects as the latitude increases from the Equator to the poles. It is the standard map projection for navigation purposes; and recommended for mapping of regions bordering the equator. However, it is inappropriate for global mapping as it exaggerates areas far from the equator. For example, Greenland appears larger than Africa, when in reality Africa's area is 14 times greater. Africa also appears to be roughly the same size as Europe, when in reality Africa is nearly 3 times larger.

### 1.3.2. Transverse Mercator:

Transverse Mercator map projection is an adaptation of the standard Mercator projection (also called Gauss Conformal or Gauss Kruger). When paired with a suitable geodetic datum, the Transverse Mercator delivers high accuracy in zones less than a few degrees in east-west extent; and recommended for mapping of regions with north-south extent - used for topographic maps at scales from 1: 20,000 to 1: 250,000.

### 1.3.3. Universal Transverse Mercator projection:

Universal Transverse Mercator (UTM) is oblique case Mercator projection. That means the cylindrical paper touches the globe along the great circle formed by two selected opposite meridians. It is a version of the Transverse Mercator, but one with a secant map surface. UTM divides the world into 60 narrow longitudinal zones of 6 degrees. The latitudinal interval is $8^0$ with the extent is from $84^0$ N to $80^0$ S. Regions above 84°N and below 80°S are not included in the system due to distortion. That means zone 1 extends from $180^0$ W to $174^0$ W.

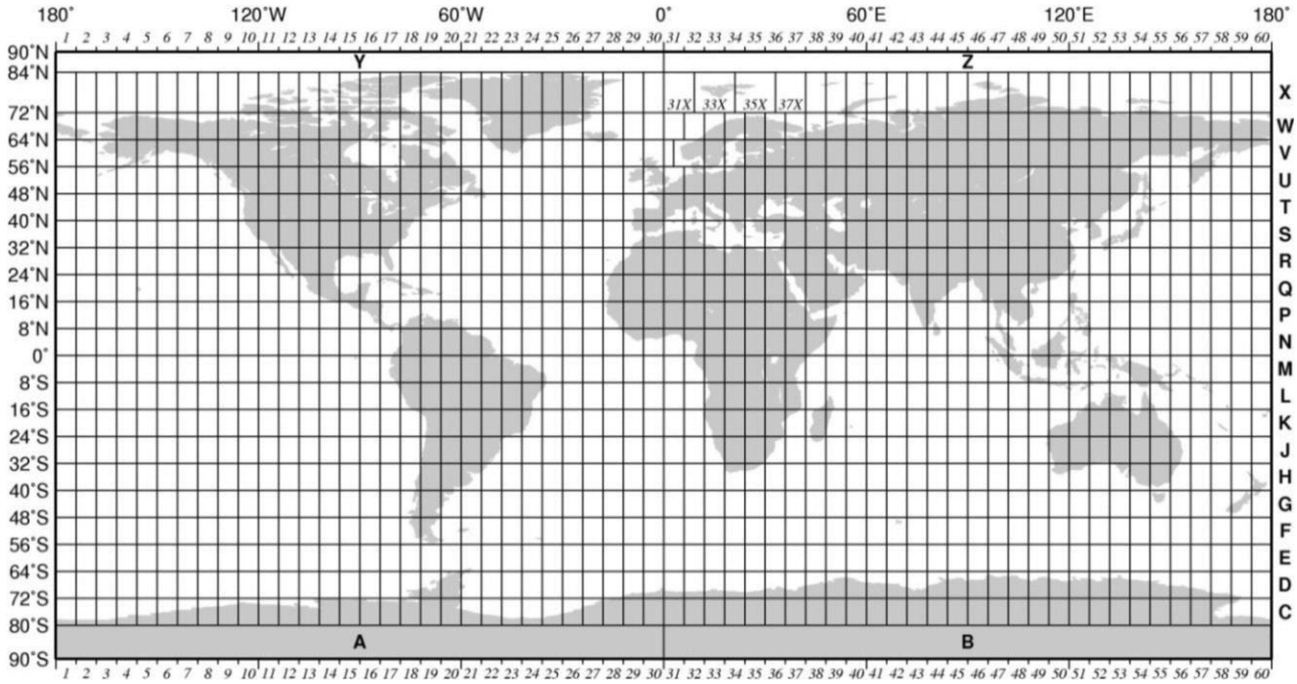


Figure:1.6 Universal Transverse Mercator zone layouts

Each zone has a central meridian. Eastings are measured from the central meridian. The central meridian is assigned a value of 500 km (500,000 meters). This is to avoid negative values. The central meridian is the false easting. For the northern hemisphere, equator is assigned the value of 0. The scale Factor (SF) is constant along each north-south coordinate grid line, but it varies in the east-west direction. The UTM grid system is widely adopted for topographic maps, satellite imagery, natural resources data bases, and other applications that require precise positioning. It is a metric system (meter is the basic unit of measurement).

### 1.4. Choosing a map projection:

A well-chosen map projection takes care that scale distortions remain within certain limits and that map properties match to the purpose of the map. Generally,

- ✓ Normal cylindrical projections are typically used to map the world in its entirety (in particular areas near the equator are shown well).
- ✓ Conical projections are often used to map the different continents (the mid-latitudes regions are shown well),
- ✓ Polar azimuthal projections may be used to map the polar areas.
- ✓ Transverse and oblique aspects of many projections can be used for most parts of the world, though they are usually more difficult to construct.

### 1.5. Projections within the GIS Environment:

In any gis software, coordinate system is used to automatically integrate the geographic locations from different datasets into a common coordinate (georeferenced) framework for display and analysis. If our spatial data reference locations are shown with decimal degrees of latitude and longitude, we can display it on gis software without employing projection. software draws the data by simply treating the latitude and longitude coordinates as planar X, Y coordinates. We might decide that we do not need to project our data. However, if we need to make measurements or would like to create an aesthetically pleasing map, you should choose a projected coordinate system.

Therefore, it is important to understand the difference between GIS tools that merely define a projection (e.g. if a shapefile has lost its projection or datum information) and tools that actually perform a projection and thus change the dataset. In addition, on-the-fly projections and transformations can be used efficiently to correctly display data given in different datums. However, the user needs to be aware that this tool only changes the display and does not alter the original dataset; hence it should not be used for spatial data analysis. It should be obvious that datum information is a crucial component of the metadata attached to any spatial dataset.