5 Geo-Referencing System

Abstract

At this point, you have learnt about the basic concept of the database in the GIS environment. The aim of this chapter is to understand our Earth's reference system and how we can manage our database in the real coordinate system to locate Earth's features. After reading this chapter you should be able to understand the following:

- Needs of the geo-reference system
- The Earth's reference system and its characteristics
- Coordinate systems and their types
- Map projection, mostly used in India—polyconic, Lambert Conformal Conic (LCC) and Universal Transverse Mercator (UTM)

Keywords

Coordinate system · Datum · Flattening · Map projection · UTM · Non-perspective projection

5.1 Introduction

In spatial data, information about location is most important and should be geo-referenced to know the location of any feature on a map, which means the map should be referenced with the Earth's coordinate system. Various spatial databases are created with different geo-reference systems by different organisations, and this requires us to bring the same geo-reference platform for the integration of databases for further geographical analysis. The literal meaning of geo-reference is to associate anything with the Earth. In other words, it is defined as positioning objects in either 2- or 3-dimensional space. So geo-referencing is a process of providing coordinate systems of the Earth to the database which may be raster or vector. The coordinate system is composed of a spheroid (a mathematical description of the Earth's shape) and map projection (a mathematical conversion from spherical to planar coordinates). Coordinate systems may be geographic or projected. This geo-referencing of databases provides the ability to measure the length, size and shape of the Earth's features.

Before understanding the coordinate system, we must know the characteristics of the globe that correspond to the Earth as offered by Mishra and Ramesh (2002):

1. The equator divides the globe into two halves, the northern and southern hemisphere.
2. The equator is perpendicular to the polar axis.
3. All parallels are parallel to the equator.

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4. Spacing between any two parallels is the same along all meridians.
5. The equator is the only great circle line of latitude. All other lines of latitudes (parallels) are shorter than the equator and are not a great circle.
6. Each meridian is one half of a great circle in length. It is the shortest line between the two poles.
7. All meridians converge at the North and South polar points.
8. Spacing between meridians is equal along a given parallel, but the space between meridians decreases pole-wards.
9. Parallels and the meridians intersect at right angles.
10. All areas are in correct scale ratio to Earth's measurements.

Properties of a map such as shape, area, distance and direction are affected by the projection system. Different projection systems preserve different properties of a map and it is not possible to include all properties of a map in a single projection.

1. **Conformality or orthomorphism** This represents the features of the Earth's surface in their true shape.
2. **Equal area or equivalence** All the features represented on it maintain their proportional sizes.
3. **True distance** Geodetic lines on the Earth which give the shortest distance between any two points appear as the shortest lines on the globe. The distance is correctly maintained.
4. **True direction** The directions of points on the globe from a given point are the same as the directions on the surface of the Earth. It represents true direction on a globe.
5. **Simplicity** The longitudes and latitudes are so precisely arranged that it becomes convenient to locate a point or network of graticules which have the property of simplicity.

5.2 Coordinate System

A coordinate system is a measurement framework or reference framework consisting of a set of points, lines and surfaces with a set of rules that are used to define the positions of points in space in either two or three dimensions. There are two types of coordinate systems: *real and geographic*, where spherical coordinates are measured from the centre of the Earth and use ellipsoid and datum; and *planar coordinate or projected coordinate system*, where the Earth's coordinates are projected into a 2-dimensional plane (Fig. 5.1). Both coordinate systems are used to present the Earth's surface with different specifications.

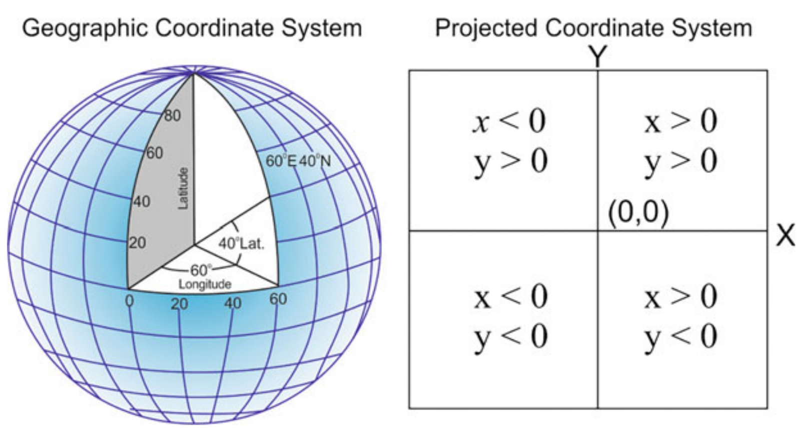


Fig. 5.1 Geographic and projected coordinate system

5.2.1 Real or Geographic Coordinate System

A reference system that uses latitude and longitude to define the locations of points on the surface of a sphere or spheroid is represented by decimal degree (0.00) and degree (Degree, Minute and Second). Longitudes and latitudes are angular measurements from the Earth's centre to a point on the Earth's surface. The longitude is measured in degrees East or West of the prime meridian (Greenwich) and latitude is measured in degrees North or South of the equatorial plane. For longitude 0°, the prime meridian, starting at the North Pole, passes through Greenwich, England and ends at the South Pole. Longitude is measured form Greenwich (0°) eastwards up to 180° and West up to −180°. For latitude 0° is the equator, 90° is at the North Pole and −90° at the South Pole. A geographic coordinate system definition includes a datum, prime meridian and angular unit. It is also known as a Universal Coordinate System and is used for locating positions on the surface of a globe. Latitude and longitude are not uniform units of measurement; one degree of longitude at the equator represents 111.321 km (Clarke 1866 spheroid) and one degree of longitude at 60° latitude represents 55.802 km (Clarke 1866 spheroid). This reference system assumes that the Earth is not a perfect sphere. The geographic coordinate system (latitude and longitude) is not efficient for measuring distances and areas.

5.2.2 Planar or Projected Coordinate System

This can be referred to as a map projection because the Earth is a spheroid and a mathematical model must be used to convert a spherical surface to a flat map sheet. There are two dimensions, x and y, which measure the distance in horizontal and vertical directions, resulting in the positions of vector and raster formats of data divided into two dimensions. This is also known as a planar or Cartesian coordinate system. Typically, the measurement unit of this system is linear, such as a metre (metric system) or foot (British system). A projected coordinate system is defined by a geographic coordinate system, a map projection, any parameter needed by the map projection and a linear unit of measurement. A map projection is the systematic transformation of locations on the Earth (latitude/longitude) to planar coordinates. The measurements of length, angle and area remain constant by this projection system. The representation of the Earth's features into two dimensions always involves distortion of some parameter such as shape, area, distance or direction. Different projections produce different types of distortions. Therefore, different types of applications require different projections.

5.3 Shape of the Earth and Datum

A datum is a set of reference points used to locate places on the Earth's surface and also determine the precise position on the Earth's surface by defining the origin and orientation of latitude and longitude lines. Satellite technology has revealed that the shape of the Earth is neither a perfect sphere nor a perfect spheroid (Fig. 5.2) due to

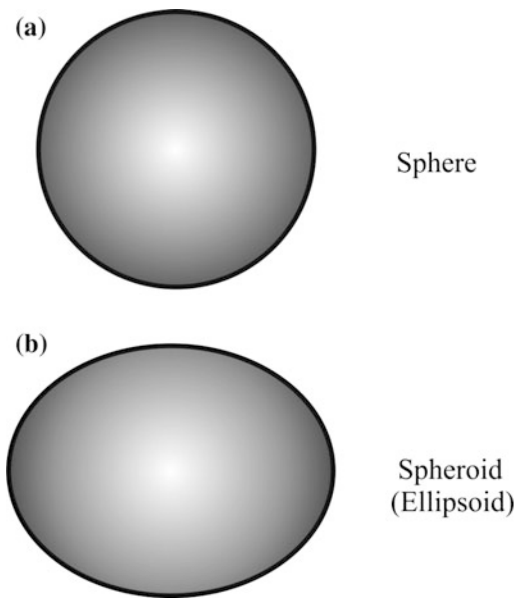


Fig. 5.2 Shape of the earth: **a** sphere, **b** spheroid

flattening at the poles as well as gravitational and surface feature variations. Ellipsoid is a mathematical figure generated by the revolution of an ellipse about one of its axes. The ellipsoid that approximates the geoid is an ellipse rotated about its minor axis, or an oblate spheroid. Ideally, a spheroid is a 3-dimensional shape or rotating figure of the Earth obtained by rotating an ellipse on its minor axis, resulting in an oblate spheroid, or about its major axis, resulting in a prolate spheroid. In other words, a spheroid is created from the 2-dimensional ellipse and the ellipse is an oval shape of the Earth with major and minor axes. It is also defined by the flattening of the Earth which is calculated by the given formula:

$$\text{Flattening} = \frac{\text{Semi-major axis} - \text{Semi-minor axis}}{\text{Semi-major axis}}$$

The flattening result lies between 0 and 1. Flattening value 0 means both axes are equal. The flattening of the Earth is approximately 0.0033. The reference specifications of a measurement system are the system of coordinate positions on a surface (a horizontal datum) or heights above or below a surface (a vertical datum). Therefore, an ellipsoid is the best-fitted shape of the Earth and assumes that the Earth has a homogenous surface with no mountains and trenches. But the Earth has irregular surfaces (mountains and trenches) causing variation in local heights. A geoid is also a model of the Earth's surface that shows the mean global sea level. A geoid is the equipotential surface in the gravity field of the Earth which approximates the undisturbed mean sea level extended continuously through the continents. The direction of gravity is perpendicular to the geoid at every point. The geoid is the surface of reference for astronomic observations and for geodetic levelling. The shape of the geoid passes through the Earth's crust (Fig. 5.3). The vertical distance between ellipsoid and geoid is called geoid height, and it ranges from −100 m (negative geoid) to +100 m (positive geoid). It is also important to know that elevations and contour lines on the Earth are reported relative to the geoid, not the ellipsoid. Latitude, longitude and all plane coordinate systems, on the other hand, are determined with respect to the ellipsoid.

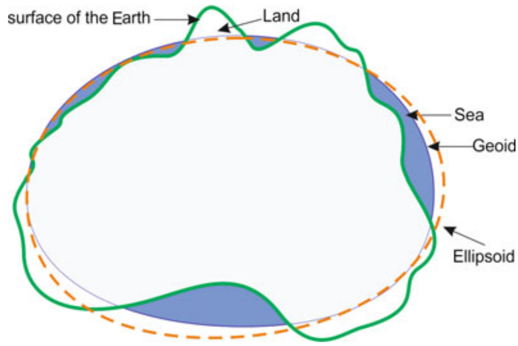


Fig. 5.3 Model of the Earth: ellipsoid, geoid and the Earth's surface

5.3.1 Geocentric Datum

In the last 15 years, satellite data have provided geodesists with new measurements to define the best earth-fitting spheroid, which relates coordinates to the Earth's centre of mass. An earth-centred or geocentric datum uses the Earth's centre of mass as the origin. The most recently developed and widely used datum is WGS 1984. It serves as the framework for locational measurement worldwide (Fig. 5.4).

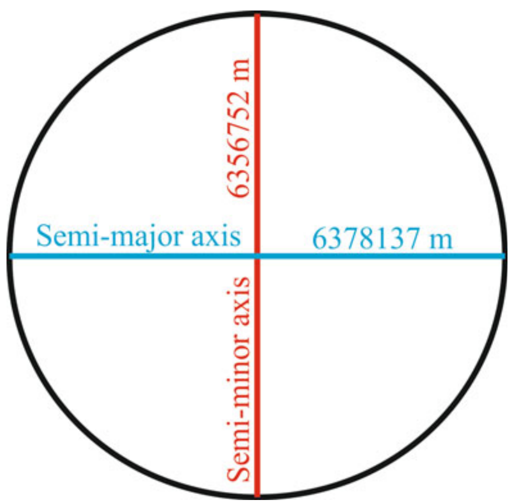


Fig. 5.4 Geocentric datum (WGS84)

Table 5.1 Ellipsoid parameters for India

Sl. No.	Ellipsoid	Semi-major axis	Semi-minor axis
1	Everest 1830	6377299.3600000003	6356098.3516280400
2	Everest adj 1937	6377276.3449999997	6356075.4131402401
3	Everest def 1962	6377301.2429999998	6356100.2301653838
4	Everest def 1967	6377298.5559999999	6356097.5503008962
5	Everest def 1975	6377299.1509999996	6356098.1451201318
6	Everest India Nepal	6377301.2429999998	6356100.2301653838
7	Everest modified (1830)	6377304.0630000001	6356103.0389931547
8	Everest modified (1969)	6377295.6639999999	6356094.6679152036
9	Indian 1954	6377276.3449999997	6356075.4131402401
10	Indian 1960	6377276.3449999997	6356075.4131402401
11	Indian 1975	6377276.3449999997	6356075.4131402401
12	WGS_1984	6378137.0000000000	6356752.3142451793

5.3.2 Local Datum

A local datum aligns its spheroid to closely fit the Earth's surface in a particular area. A point on the surface of the spheroid is matched to a particular position on the surface of the Earth. This point is known as the origin point of the datum. The coordinates of the origin point are fixed, and all other points are calculated from it (Shekhar 2015) – e.g. the Everest datum is used to locate the Indian sub-continent (Snyder 1987) (Table 5.1).

5.4 Map Projection

Map projection is a systematic drawing of parallels of latitude and meridians of longitude on a plane surface for the whole Earth or part of it on a certain scale so that any point on the Earth's surface may correspond to that on the drawing (Singh and Singh 2009). According to Snyder (1987), a map projection is a systematic representation of all or part of the surface of a round body, especially the Earth, on a plane. In other words, a map projection is one which represents longitude and latitude in the same way as a globe on a flat surface. There are various projection systems by which the curved surface of the Earth is portrayed on a flat surface (Fig. 5.5).

Basically, various criteria are used for classification of projection. On the basis of source of light, map projection can be perspective and non-perspective. Perspective projections are created by projecting latitude and longitude as true geometric projections by the source of light on the plane surface. It can be visualised as a transparent globe with a light bulb at its centre (though not all projections originate from the globe's centre, it can be three positions such as one of pole, equator and in-between pole and equator) casting lines of latitude and longitude into a sheet of paper. Generally, the paper is either flat or placed tangentially to the globe (a planar or azimuthal projection) or formed into a cone or cylinder and placed over the globe (cylindrical and conical projections). When the source of light is placed at the centre of the globe to project toward the North or South Pole this is known as gnomonic projection. Where the source of light is placed at a pole to project toward the opposite pole this is known as stereographic projection, and when the source of light is infinite to project this is known as orthographic projection (Fig. 5.6). Map projection can be categories on the basis of tangent

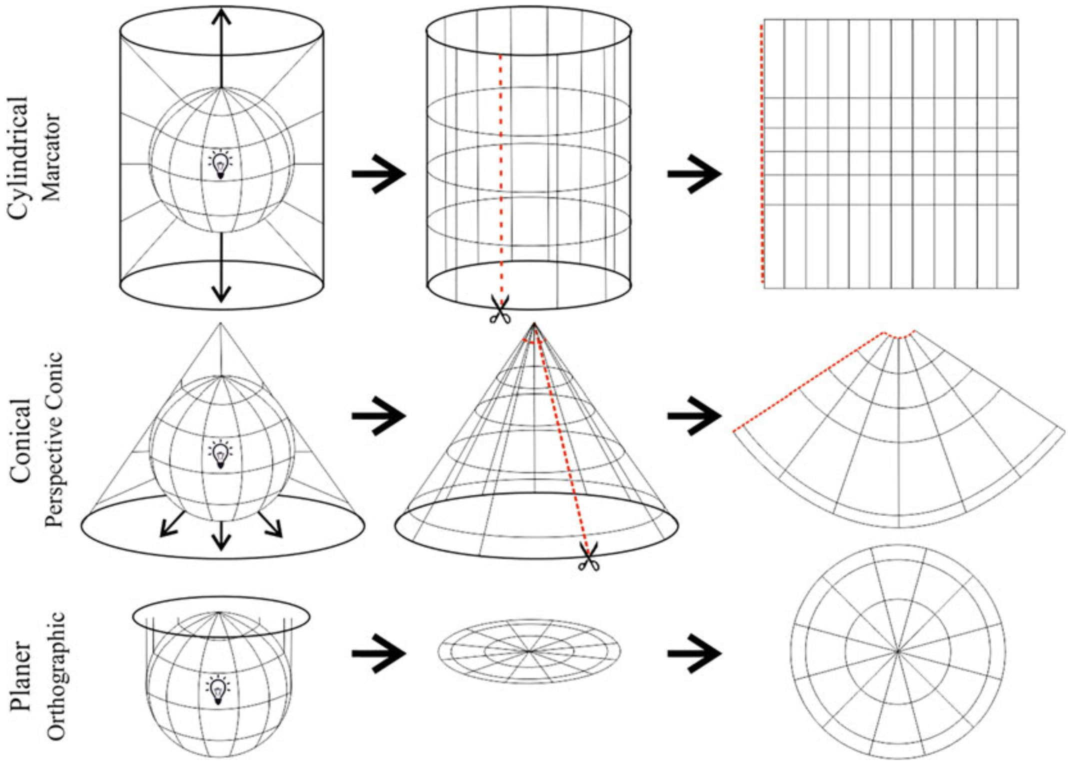


Fig. 5.5 Type of map projection

and secancy. Cylindrical, conical and planar projection are shown in Fig. 5.7. This is basically a different tangent plane where a network of latitude and longitude is projected. If the tangent surface is parallel to the pole this is known as transverse projection. When the tangent surface is perpendicular to the equator this is known as normal projection, and when the tangent plane is in-between normal and transverse it is known as oblique projection.

Fig. 5.6 Perspective projection

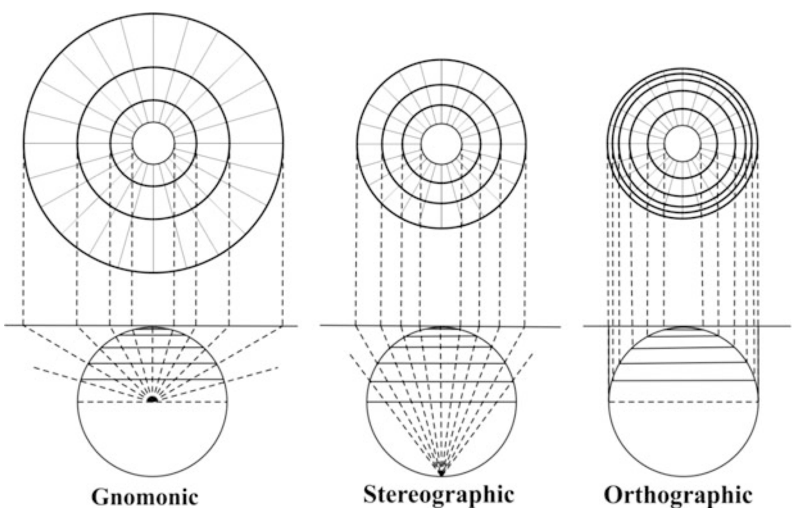
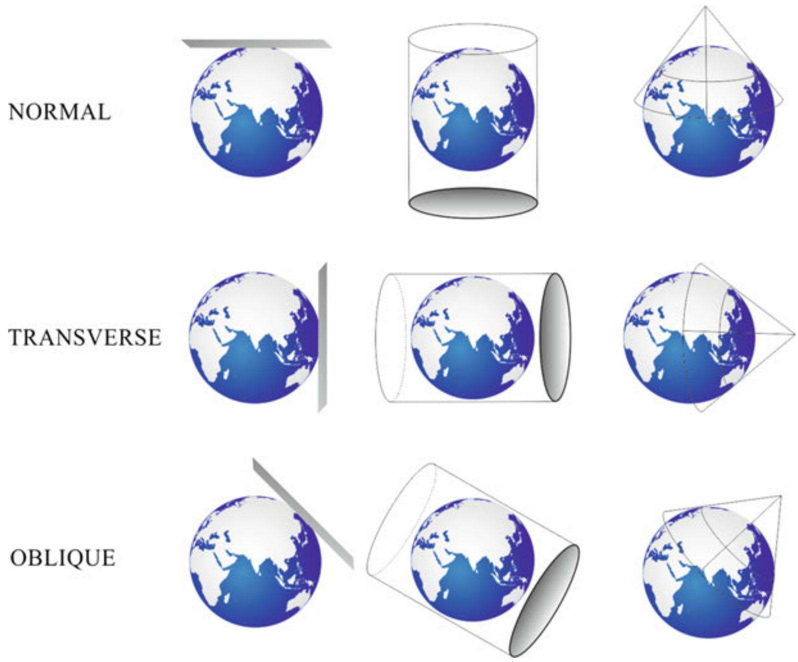


Fig. 5.7 Tangent projection



Non-perspective projections are formed with the longitude and latitude networks of curved or straight lines as well as spacing between longitudes and latitudes reduced or enlarged. On the basis of a developable surface, it can be cylindrical, conical and plane (zenithal or azimuthal). When a cylinder is wrapped around the globe that touches the equator throughout its circumference, the network of latitude and longitude is projected on the cylinder. When a cylinder is cut along longitude and unrolled, then the cylindrical projection is formed with straight latitude and longitude. Mercator's projection is one example of cylindrical projection. When a cone is placed over the globe and its peak along the polar axis of the globe and the surface of the cone touches the globe along latitude, the network of latitude and longitude projected over the cone is basically known as conical projection. Single standard parallel conical projection is an example of conical projection. When a plane tangent to the globe pole and longitude is projected as straight lines radiated from the pole towards the equator as well as latitude formed as complete circles, this is centred on the pole to make planar projection. Gnomonic and stereographic projection form the planar projection. Map projection generally requires a systematic mathematical transformation of the Earth's longitude and latitude into a plane. Every map projection has some distortion to preserve some characteristics of a globe in terms of distance, area, shape or direction. It is a choice of a cartographer to choose certain characteristics of the globe at the expense of others. On the basis of global characteristics, a map projection can be equal-area, conformal and azimuthal. There are three main cartographic criteria that are applied to the evaluation of map projection properties: *equidistance* – correct representation of distance, usually one or more lines on a map along which the scale remains true, but the scale is not correct throughout the map (equidistant projections); *conformality or orthomorphism* – correct representation of shape – orthomorphic is derived from two words, *orthos* meaning 'straight' and *morphe* meaning 'shape', so the relative local angles about every point on the map are shown correctly; and *equal area or equivalence* – correct representation of area but the shapes, angles and scale are distorted on most parts of a map. There are thousands of map projections varying by choosing different points on the Earth as the centre or as a starting point of projection. But there are three basic types of developable surfaces onto which most map projections are based: cylindrical, conical and azimuthal.

There are two methods for map projection in a GIS environment: direct, in which one maps from ellipsoidal to projection surface; and double, which involves a transformation from ellipsoidal to spherical surfaces and from the spherical to the projection surface. Before creating a map on any projection system, one needs to provide a datum or ellipsoid. The proper scale should be specified according to the output material size and the appropriate projection system chosen on which basis the map should be transformed (Fig. 5.8). The Indian grid system was designed during British periods, dividing India into nine zones in the Lambert Conformal Projection. The topographical map of India is on 1:25,000, 1:50,000 and 1:250,000 scales and on polyconic projection, and now it is being converted to the Universal Transverse Mercator (UTM) projection. So, polyconic projection, Lambert Conformal Conic projection (LCC), Transverse Mercator and Universal Transverse Mercator (UTM) projections are widely used for India.

5.4.1 Polyconic Projection

Polyconic projection was developed by Ferdinand Hassler, First Superintendent of the US Coast Survey, in 1820 for mapping of the eastern

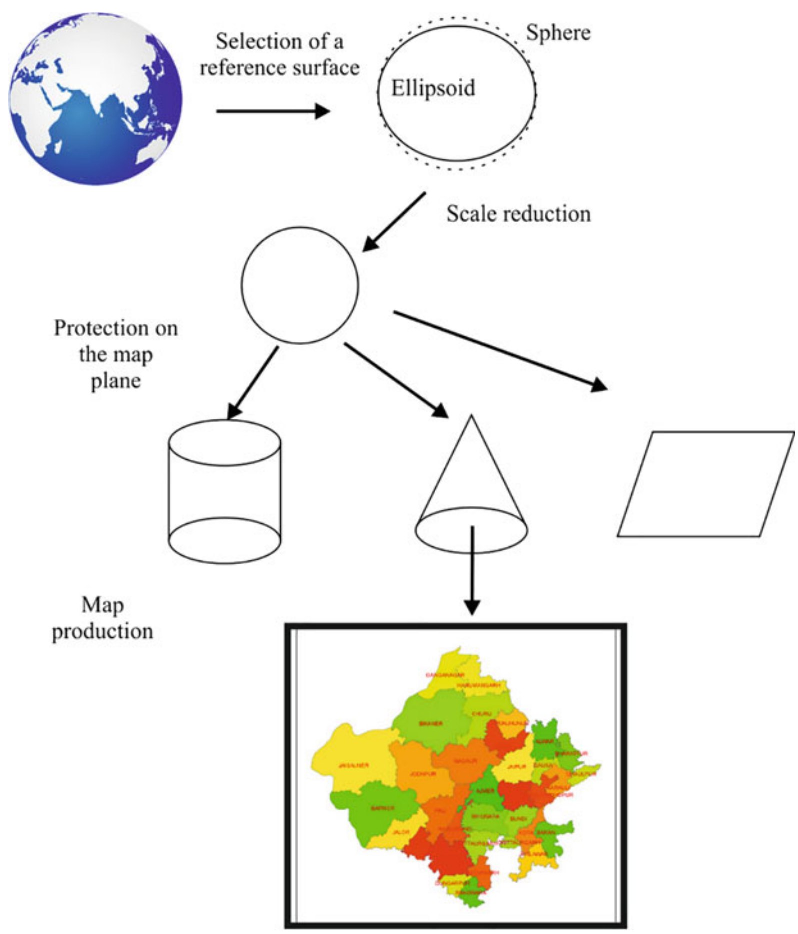


Fig. 5.8 Flow diagram of map-projection system

coast of the USA. This refers to the projection methodology. This affects the shape of the meridians. Unlike in other conic projections, the meridians are curved rather than linear. The Polyconic Projection, usually called the American Polyconic in Europe, achieved its name because the curvature of the circular arc for each parallel on the map is the same as it would be following the unrolling of a cone which had been wrapped around the globe tangent to the particular parallel of latitude, with the parallel traced onto the cone. Thus, there are many ('poly') cones involved, rather than the single cone of each regular conic projection. The Polyconic Projection is neither equal-area nor conformal. Along the central meridian, however, it is both distortion-free and true to scale. Each parallel is true to scale, but the meridians are lengthened by various amounts to cross each parallel at the correct position along the parallel, so that no parallel is standard in the sense of having conformality (or correct angles), except at the central meridian. Near the central meridian distortion is extremely small. Parallels of latitude (except for the equator) are arcs of circles, but are not concentric. The central meridian and equator are straight lines; all other meridians are complex curves. The scale of this projection is true along each parallel and along the central meridian, but no parallel is 'standard'. There is no distortion in local shape along the central meridian. Distortion increases with distance from the central meridian; thus, East–West distortion is greater than North–South distortion. The area, distance and local angle are accurate along the central meridian but are distorted with increases in the distance from the central meridian (Figs. 5.9 and 5.10). This projection was used for 7½- and 15-min

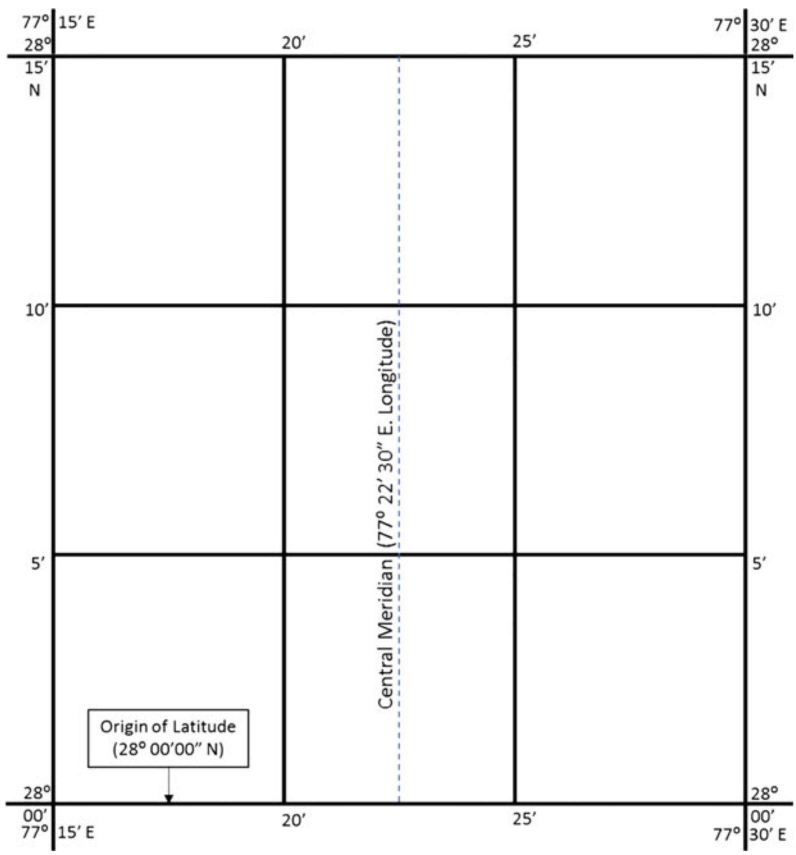


Fig. 5.9 Projection parameter for polyconic projection

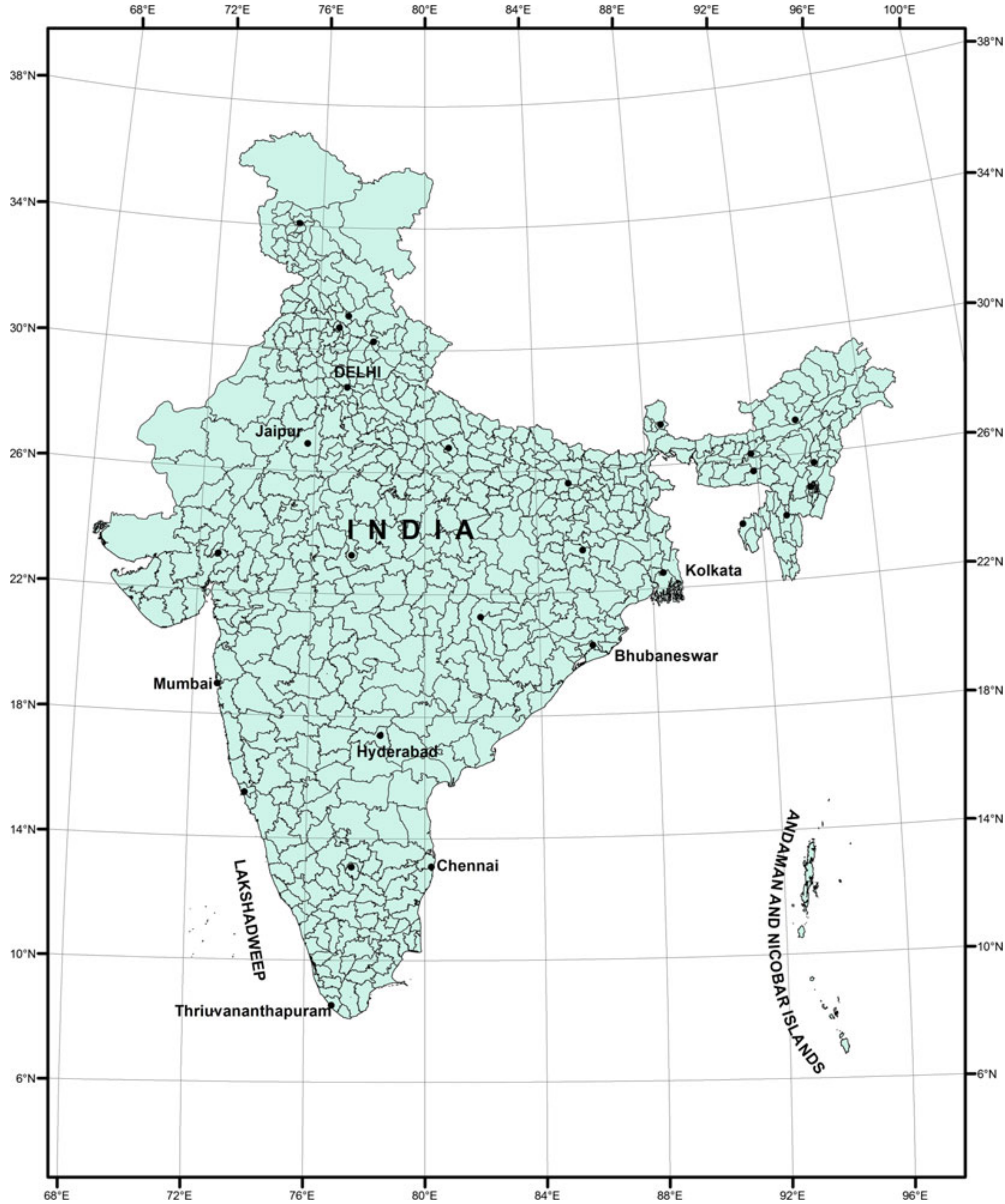


Fig. 5.10 India on a polyconic projection

topographic USGS quad sheets from 1886 until approximately 1957. It was also used in the Survey of India Topographical sheet on 1:50,000 and 1:25,000 in India.

Suppose you have a map sheet which extended between 77° 15′ East to 77° 30′ East longitude and 28° 00′ North to 28° 15′ North latitude, the parameters would be as follows:

Name of projection	Polyconic
Longitude of central meridian	77° 22′ 30′
Latitude of origin of projection	28° 00′ 00′
False easting at central meridian	00
False northing at origin	00
Unit	Metre

The central meridian of the toposheet will be mid-value of the extent of the toposheet, and sometimes the region of study is extended over the large area, and in that case the central meridian will be mid-value of longitudinal extent. The origin of the projection is the lowest extent of latitude of the study area or toposheet. The false easting or northing is a value assigned to the origin of eastings or northings in a grid coordinate system, to avoid the inconvenience of using negative coordinates. Easting is the eastward reading or left-to-right reading of grid values on a map, similarly northing is the northward or bottom-to-top reading of grid values.

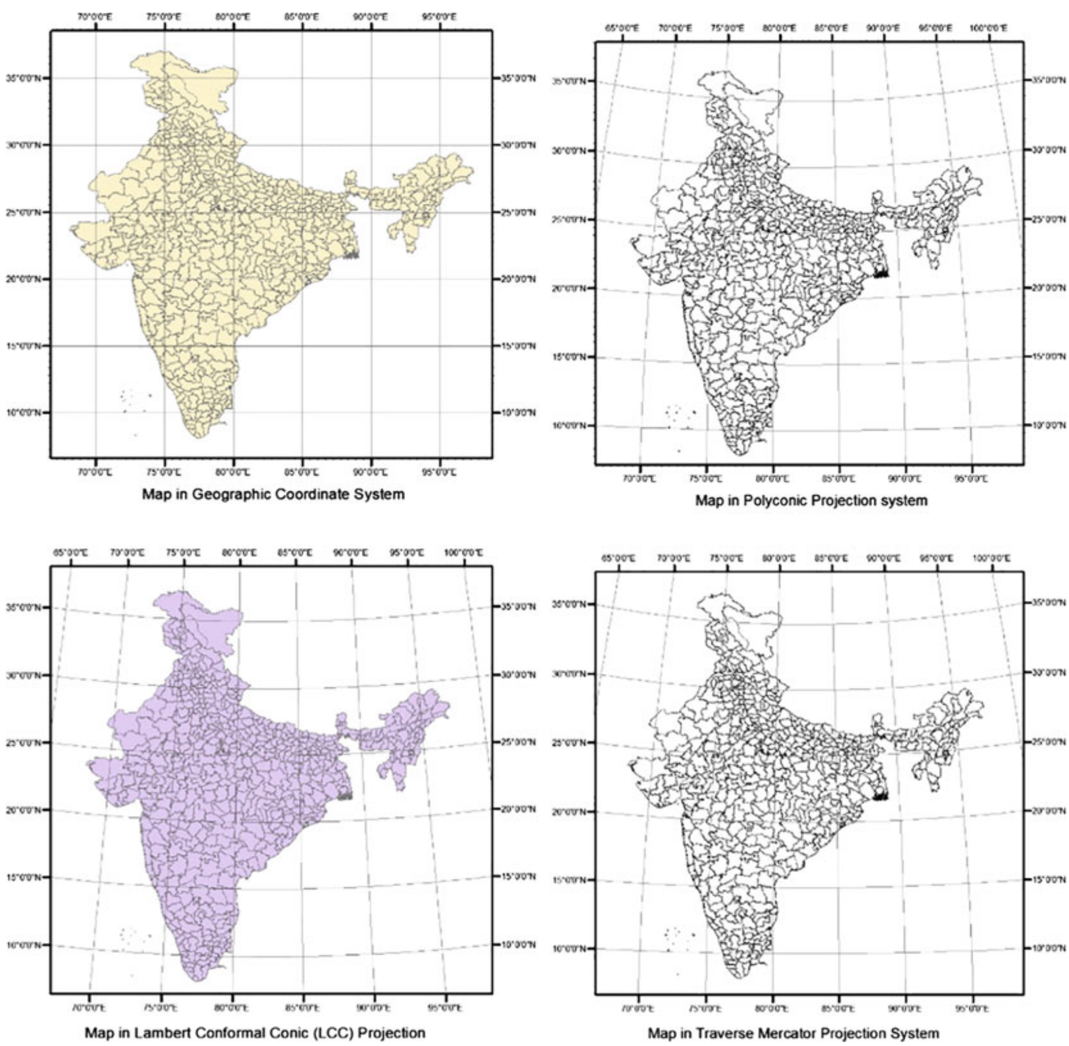


Fig. 5.11 Comparison of maps in different projections

5.4.2 Lambert Conformal Conic (LCC) Projection

The Lambert Conformal Conic projection is a modified conical projection for mid-latitude countries developed by Johann Heinrich Lambert. This projection consists of one and two standard parallels. The spacing between latitude increases beyond the standard parallels. The scale along the standard parallels is correct. It is reduced between the parallels and increases beyond standard parallels. Direction and shape are maintained in this projection. There is minimum distortion in area near standard parallels (Fig. 5.11). This projection is best suited for countries where East–West extent is more and total latitude range should not exceed 35°. The following parameters are important while using this projection:

Name of projection	Lambert Conformal Conic
Central meridian	82° 30′ 00′ E
Latitude of origin	08° 00′ 00′ N
Standard parallel	1 23° 30′ 00′ N
Standard parallel	223° 30′ 00′ N (*if one standard parallel projection is used then value of standard parallel 1 should be put in the standard parallel 2*)
False easting	00
False northing	00

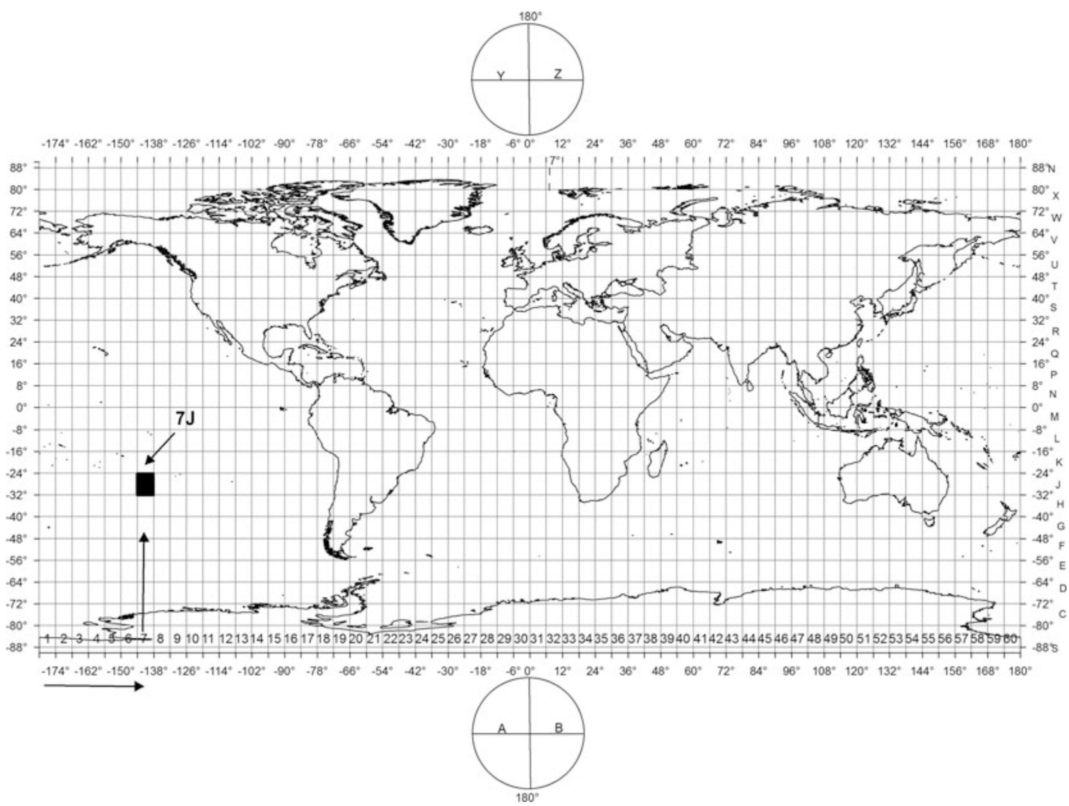


Fig. 5.12 Universal Transverse Mercator (UTM) grid for the world

5.4.3 Universal Transverse Mercator (UTM) Projection

The Universal Transverse Mercator (UTM) projection and grid were adopted by the US Army in 1947 for designating rectangular coordinates on large-scale military maps of the entire world. The UTM is the ellipsoidal Transverse Mercator to which specific parameters, such as central meridians, have been applied. The Earth, between latitude 84° North and 80° South, is divided into 60 zones, each generally 6° wide in longitude. Bounding meridians are evenly divisible by 6°, and zones are numbered from 1 to 60 proceeding East from the 180th meridian from Greenwich with minor exceptions. There are English alphabetical letter designations from South to North. From latitude 84° North and 80° South to the respective poles, the Universal Polar Stereographic (UPS) projection is used instead of UTM. Each geographic location in the UTM projection is given x and y coordinates in metres (Fig. 5.12).

In the Northern Hemisphere, the equator at the central meridian is considered the origin, with an x coordinate of 500,000 m and y of 0 m. For the

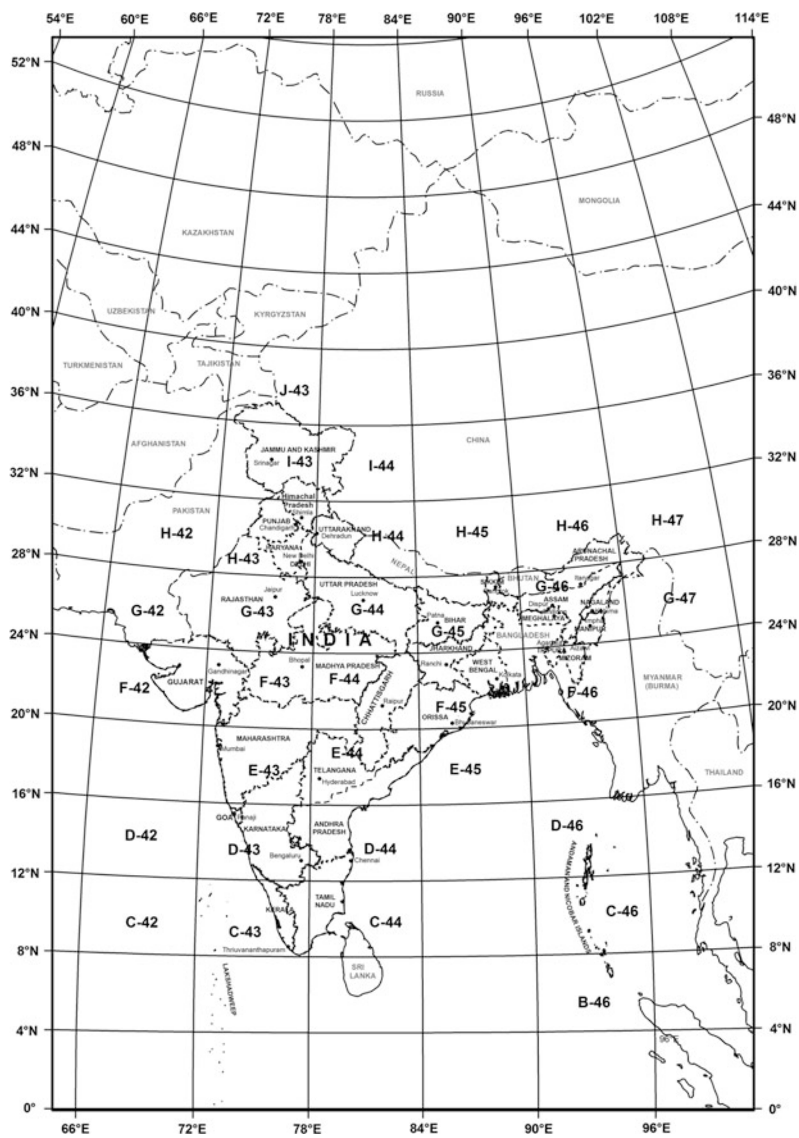


Fig. 5.13 Universal Transverse Mercator (UTM) grid zone designations for India

Southern Hemisphere, the same point is the origin, but, while x remains 500,000 m, y is 10,000,000 m. In each case, numbers increase toward the East and North. Negative coordinates are thus avoided in this projection. The ellipsoidal earth is used throughout the UTM projection system, but the reference ellipsoid changes with the particular region of the Earth. Now in India, Survey of India is using UTM projection with WGS 84 ellipsoid (Fig. 5.13).

5.5 Choice of Projection

The following should be considered while choosing map projection (see Table 5.2):

- Initially, a similar projection should be chosen which is mentioned in the map while transforming.
- To show the distribution map or any thematic map, equal-area projections should be used.
- For presentation maps usually conformal projections and equal-area projections can be used.
- Navigational maps should be made on Mercator, true direction and equidistant projections.
- The projection should be chosen according to the extent of the map, such as world, continent, state or small area. Location of an area is also important while choosing projections, such as equatorial, mid-latitude or polar region.

Table 5.2 Choice of projection

	Properties		Projection
1	***World (Earth should be treated as a sphere)***		
	Conformal *(gross area distortion)*	Constant scale along the equator	Mercator
		Constant scale along meridian	Transverse Mercator
		Constant scale along oblique great circle	Oblique Mercator
	Equal-area	Standard without interruption	Hammer
			Mollweide
			Eckert IV or VI
			Sinusoidal
		Interrupted for land or ocean	Mollweide
			Sinusoidal
		Oblique aspect to group continents	Oblique Mollweide
	Equidistant	Centred on a pole	Polar Azimuthal Equidistant
		Centred on a city	Oblique Azimuthal Equidistant
	Straight rhumb lines		Mercator
	Compromise distortion		Miller Cylindrical
			Robinson

(continued)

Table 5.2 (continued)

	Properties			Projection
2	***Hemisphere (Earth should be treated as a sphere)***			
	Conformal			Stereographic (any aspect)
	Equal-area			Lambert Azimuthal Equal-Area (any aspect)
	Equidistant			Azimuthal Equidistant (any aspect)
	Global look			Orthographic (any aspect)
3	***Continent, ocean, or smaller region (Earth should be treated as a sphere for larger continents and oceans and as an ellipsoid for smaller regions, especially at a larger scale)***			
	Predominant East–West extent	Along the equator	Conformal	Mercator
			Equal-area	Cylindrical Equal-Area
		Away from the equator	Conformal	Lambert Conformal Conic
			Equal-area	Albers Equal-Area Conic
	Predominant North–South extent		Conformal	Transverse Mercator
			Equal-area	Transverse Cylindrical Equal-Area
	Predominant oblique extent *(for example: North America, South America, Atlantic Ocean)*		Conformal	Oblique Mercator
			Equal-area	Oblique Cylindrical Equal-Area
	Equal extent in all directions *(for example: Europe, Africa, Asia, Australia, Antarctica, Pacific Ocean, Indian Ocean, Arctic Ocean, Antarctic Ocean)*	Centre at pole	Conformal	Polar Stereographic
			Equal-area	Polar Lambert Azimuthal Equal-Area
		Centre along Equator	Conformal	Equatorial Stereographic
			Equal-area	Equatorial Lambert Azimuthal Equal-Area
		Centre away from a pole or the equator Azimuthal Equal-Area	Conformal	Oblique Stereographic
			Equal-Area	Oblique Lambert
	Straight rhumb lines (principally for oceans)			Mercator
	Straight great-circle routes			Gnomonic (for less than hemisphere)
	Correct scale along meridians	Centre at a pole		Polar Azimuthal Equidistant
		Centre along the equator		Equidistant Cylindrical
		Centre away from a pole or the equator		Equidistant Conic

Source Modified after Snyder (1987)

5.6 Conclusion

In geo-referencing of the spatial database it is important to understand the location of particular features and phenomena on the Earth's surface. The huge size of the Earth is not represented in same-size but the model of the Earth is represented in a reduced size, i.e. globes with their characteristics of true shape, equal area, true distance, true direction and simplicity. The coordinate system of the Earth is a reference system which is used for mapping a 3-dimensional Earth or any part of the Earth to a 2-dimensional plane. In GIS, two types of coordinate systems are used; geographic and planer. While mapping the Earth's features on any projection system, datum is used to locate the precise position because the shape of the Earth is spheroid due to flattening at the poles. There are two types of datum used while mapping: geocentric and local. There are various families of projection systems available – cylindrical, conical and azimuthal – to represent the various locations of the Earth's surface. In India, Polyconic, Lambert Conformal Conic (LCC) and Universal Transverse Mercator (UTM) projections are widely used to represent small-scale to large-scale maps.

Questions

1. What is a geo-referencing system? Why is it needed in GIS?
2. What are the basic properties of a globe to understand with regard to coordinate systems?
3. What is a coordinate system? Discuss the type of coordinate systems used in a GIS environment.
4. What is a datum in GIS? Discuss the types and uses of datum to represent our maps.
5. What is map projection? Why do we need different map projections for different locations on Earth?
6. Discuss a type of map projection with special reference to India.

References

Misra RP, Ramesh A (2002) Fundamentals of cartography. Concept Publishing Company, New Delhi

Shekhar R (2015) Designing a thematic map. RK Books, New Delhi

Singh RB (2009) Remote sensing and geographical information system. In: Bhat LS (ed) Geography in India—selected themes. Pearson Publication, Delhi, pp 203–257

Singh RL, Singh PB (2009) Elements of practical geography. Kalyani Publishers, New Delhi

Snyder JP (1987) Map projection–a working manual. United States Government Printing Office, Washington