Map Projection Concepts & Use in RS & GIS

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Statistics about the Earth

➢ Surface Area	:	510.1 million km^2
➢ Mass	:	$5.97237*10^{24}$ Kg.
➢ Equatorial Radius	:	6378.137 Km.
➢ Polar Radius	:	6356.752 Km.
➢ Flattening	:	0.0033528
➢ Age	:	4.5 Billion Years
➢ Elevation of Land	:	8848 m (ME)
➢ Tectonic plates	:	7 (African, Antarctic, Australian, Eurasia, North American, South American, Pacific)

Earth Seen from Space

- For surveying and mapping, most of the measurements are taken on the Earth surface.

- The surface of the Earth is an irregular surface. Directly using these measured values for further computations of distances, area, volume etc. will give wrong results, because the irregular surface of the Earth is not mathematical.

We need a mathematical surface which can closely represent the Earth.

We need a Model of the Earth

- All the measurements can then be reduced to that surface for computations

- Once the Model of the Earth is decided, we need to locate the positions of the features.

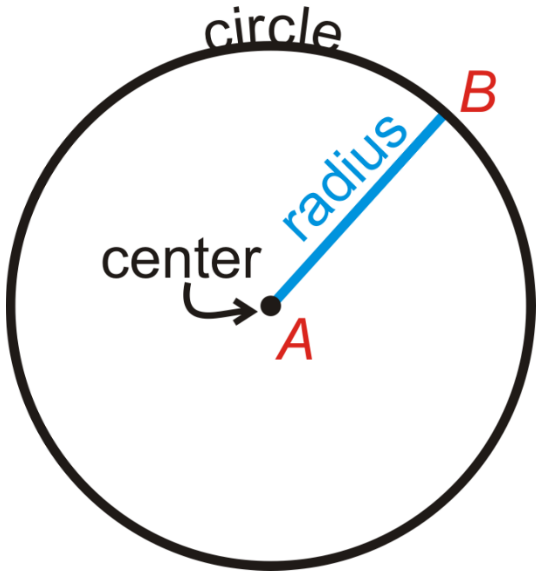
- **Everything is Relative**

- Example: Height of a point (**Height above - - ? - -**)
- Distance of a place (**From - - ? - -**)

- **We need a Coordinate System / Reference System / Datum for defining the positions**

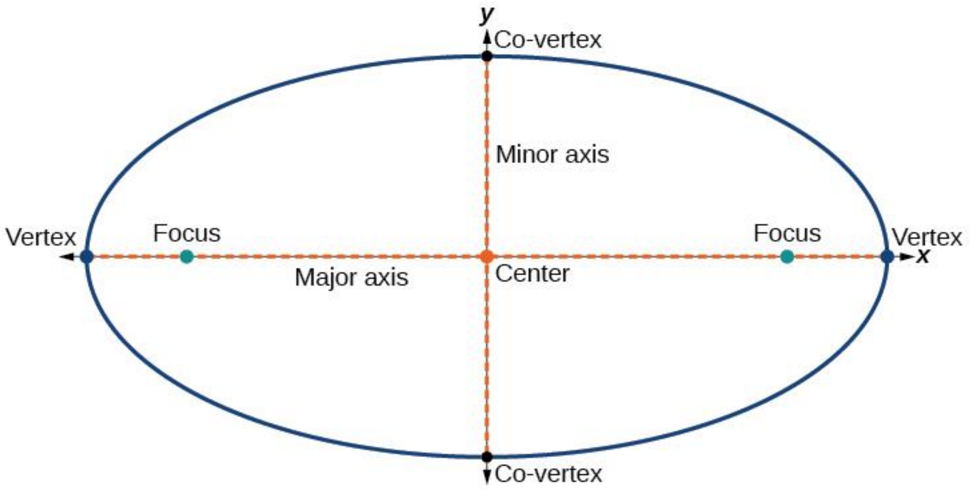
- We know that the Earth is not perfectly spherical.
- How to represent the shape of the Earth?
- The shape of the Earth can be best represented by an Ellipsoid

Circle



$$x^2 + y^2 = a^2$$

Ellipse



$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

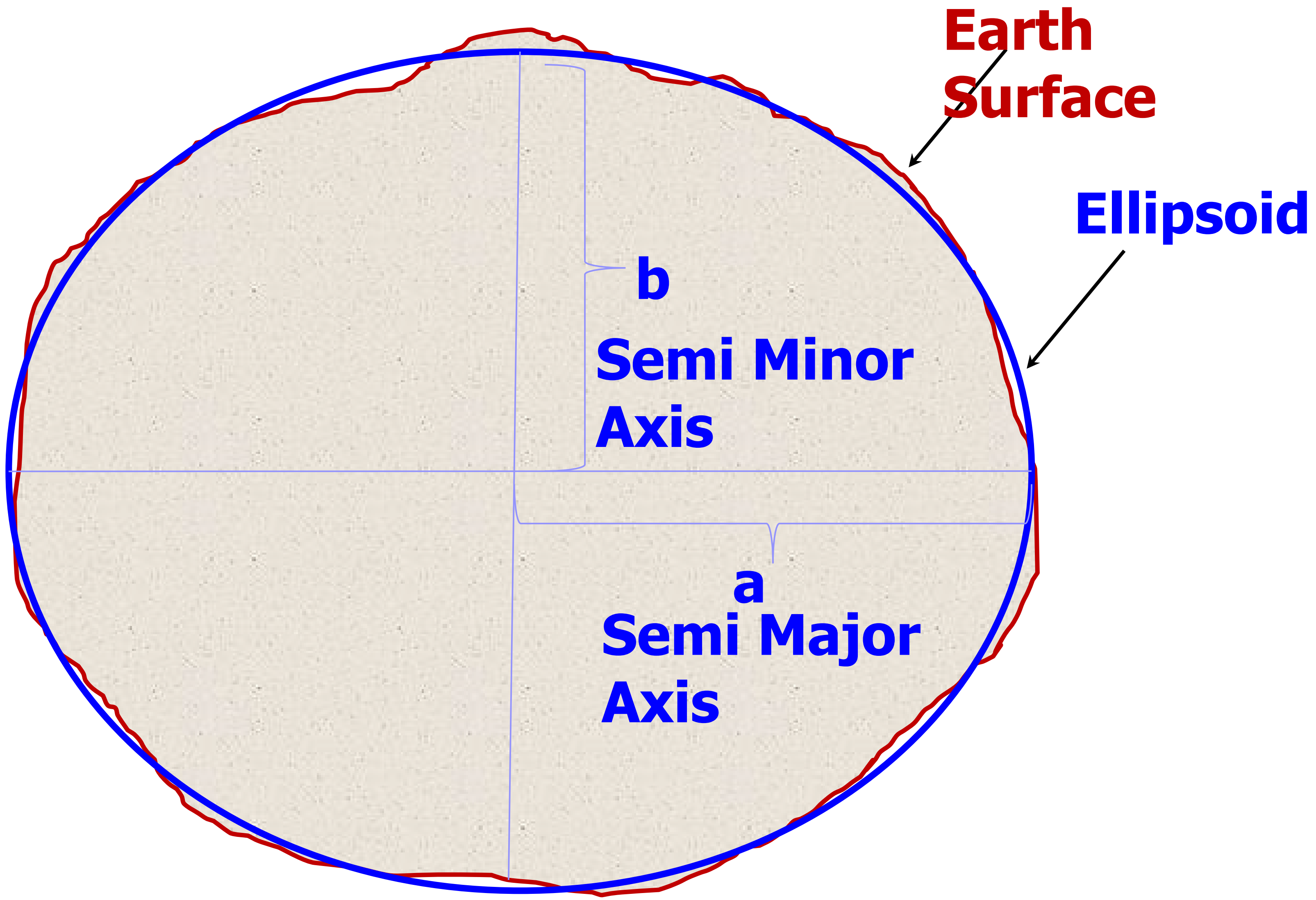
Reference Ellipsoid

- An **Ellipsoid** is the mathematical surface which can be generated by rotating an ellipse about its minor axis. Such ellipsoid is called an Oblate Ellipsoid.

- **Semi Major Axis : a** **Semi Minor Axis : b**
- **Eccentricity** $e^2 = (a^2 - b^2)/a^2$
- **Flattening** $f = (a-b)/a$

- A Reference Ellipsoid has its centre a close approximation of center of mass of Earth and minor axis is parallel to axis of rotation of Earth.

- Latitude, Longitude and Ellipsoidal Heights are defined on Reference Ellipsoid.



Earth
Surface
Ellipsoid
b
Semi Minor
Axis
a
Semi Major
Axis

Types of Reference Ellipsoid

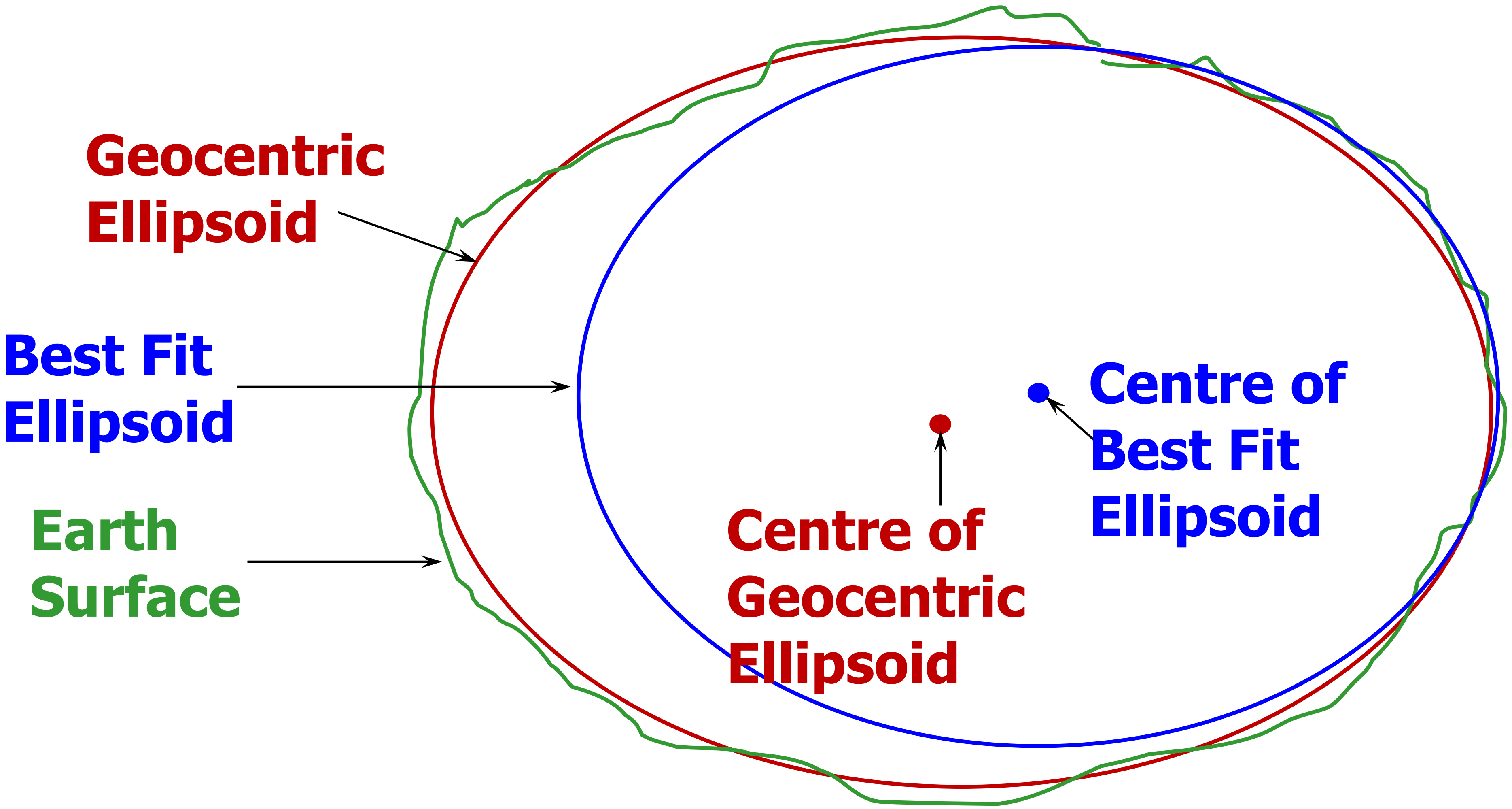
- **Best Fit Ellipsoid**

This ellipsoid is based on the measurements within a region so it best fits that region only. The center of such reference ellipsoid does not coincide with the center of gravity of the Earth. An example of such type of ellipsoid is **Everest Ellipsoid**, which was used in India.

- **Geocentric Ellipsoid**

As the name suggests, the center of geocentric ellipsoid coincides with the center of the Earth. This type of the ellipsoid can be used worldwide. An examples of this type of ellipsoid are

GRS 80 Ellipsoid and **WGS 84 Ellipsoid**.



Best Fit Ellipsoid and Geocentric Ellipsoid

Indian Datum

- The Indian geodetic datum used till few years back, was realized during 19th century.

- It was a result of Great Trigonometric Survey (GTS) carried out from 1802 to 1839. The conventional triangulation method was used as it was the best available technique at that time. The series of connected triangles from southernmost point of India up to the Himalayan foothills was used to compute the arc distance what was named the 'Great Arc'.

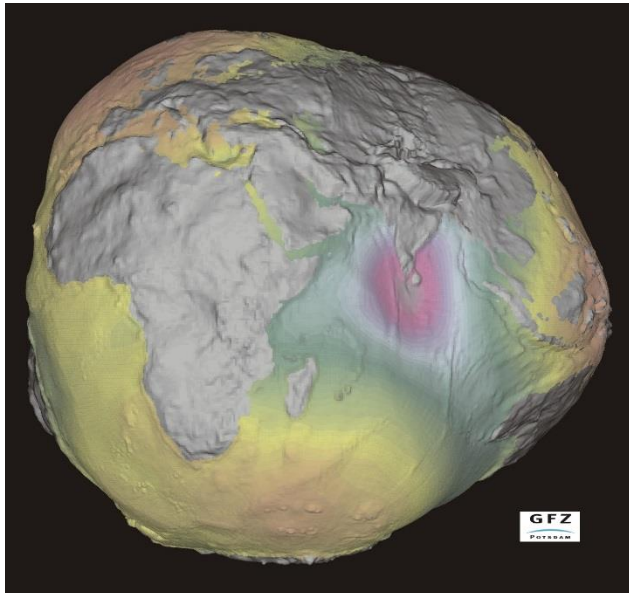
- The Great Arc measurements were used to determine the geometrical parameters (semi major axis and semi minor axis) to define the reference ellipsoid which was named after Sir George Everest as Everest Ellipsoid. This is a locally fit ellipsoid with following parameters:

	Everest	GRS 80
Semi major axis	a = 6377301.243 m	a = 6378137 m
Semi minor axis	b = 6356100.231 m	b = 6356752.314 m


BAY OF BEN
MADRAS
CALCUTTA
INDEX CHART
TO THE
GREAT TRIGONOMETRICAL SURVEY
OF
INDIA
SHOWING COLONEL LAMBTON'S NET WORK OF TRIANGULATION IN SOUTHERN INDIA.
THE MERIDIONAL AND LONGITUDINAL CHAINS OF PRINCIPAL TRIANGLES.
THE BASE LINES MEASURED WITH THE COLBY APPARATUS.
THE LINES OF THE SPIRIT LEVELLING OPERATIONS.
THE ASTRONOMICAL, PENDULUM & TIDAL STATIONS.
THE LONGITUDINAL ARCS.
AND THE SECONDARY TRIANGULATION TO FIX THE PEAKS OF
THE HIMALAYAN & THE SULIMAN RANGES.
AND THE POSITIONS OF BANGKOK, KANDAHAR &c.

Geoid

Graphical Representation of the Geoid



Geoid is an equipotential surface/Level Surface of earth's gravity field which best fits the Mean Sea Level (MSL).

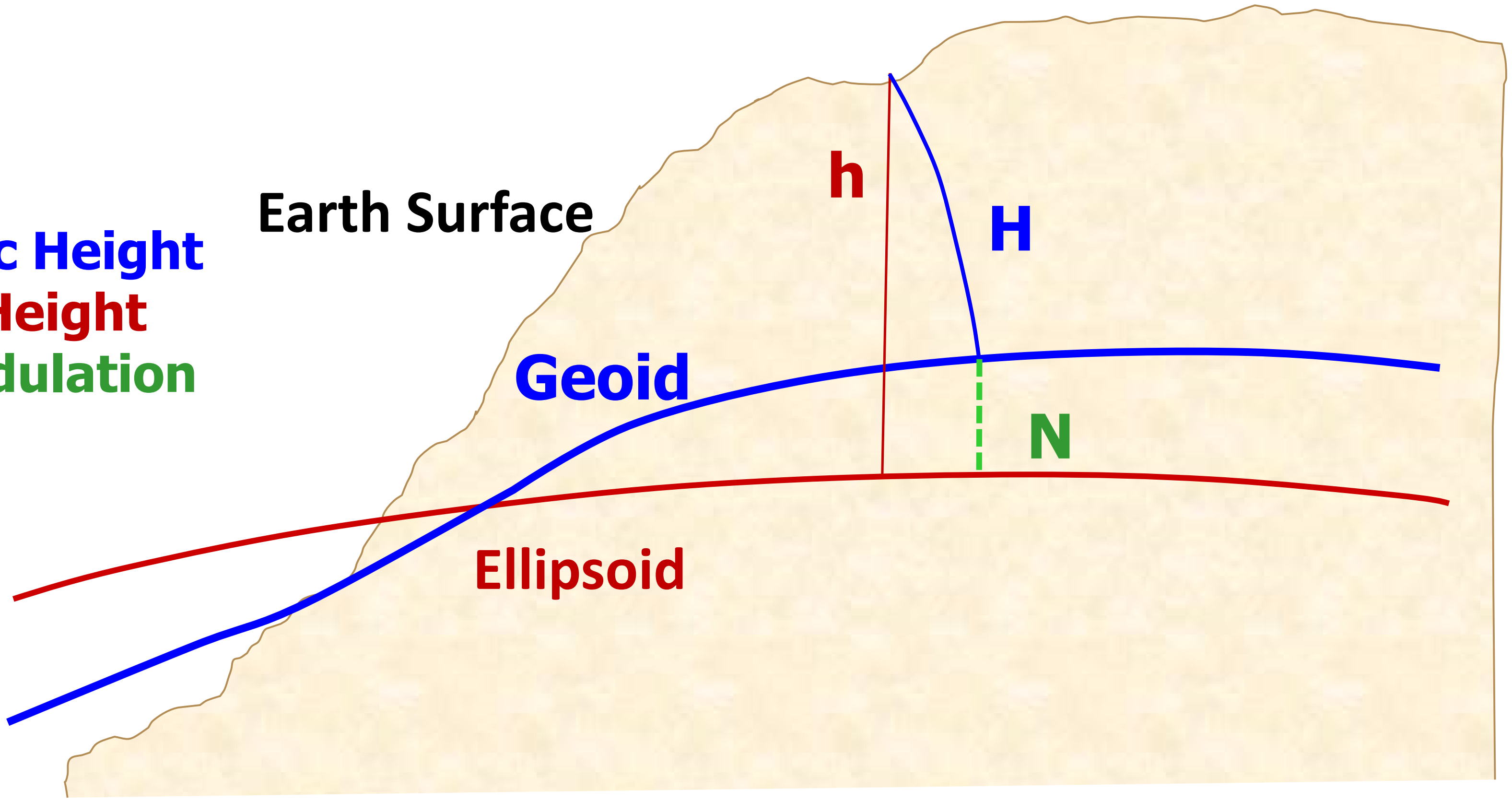
It is nearly ellipsoidal but a complex surface (not a mathematical surface).

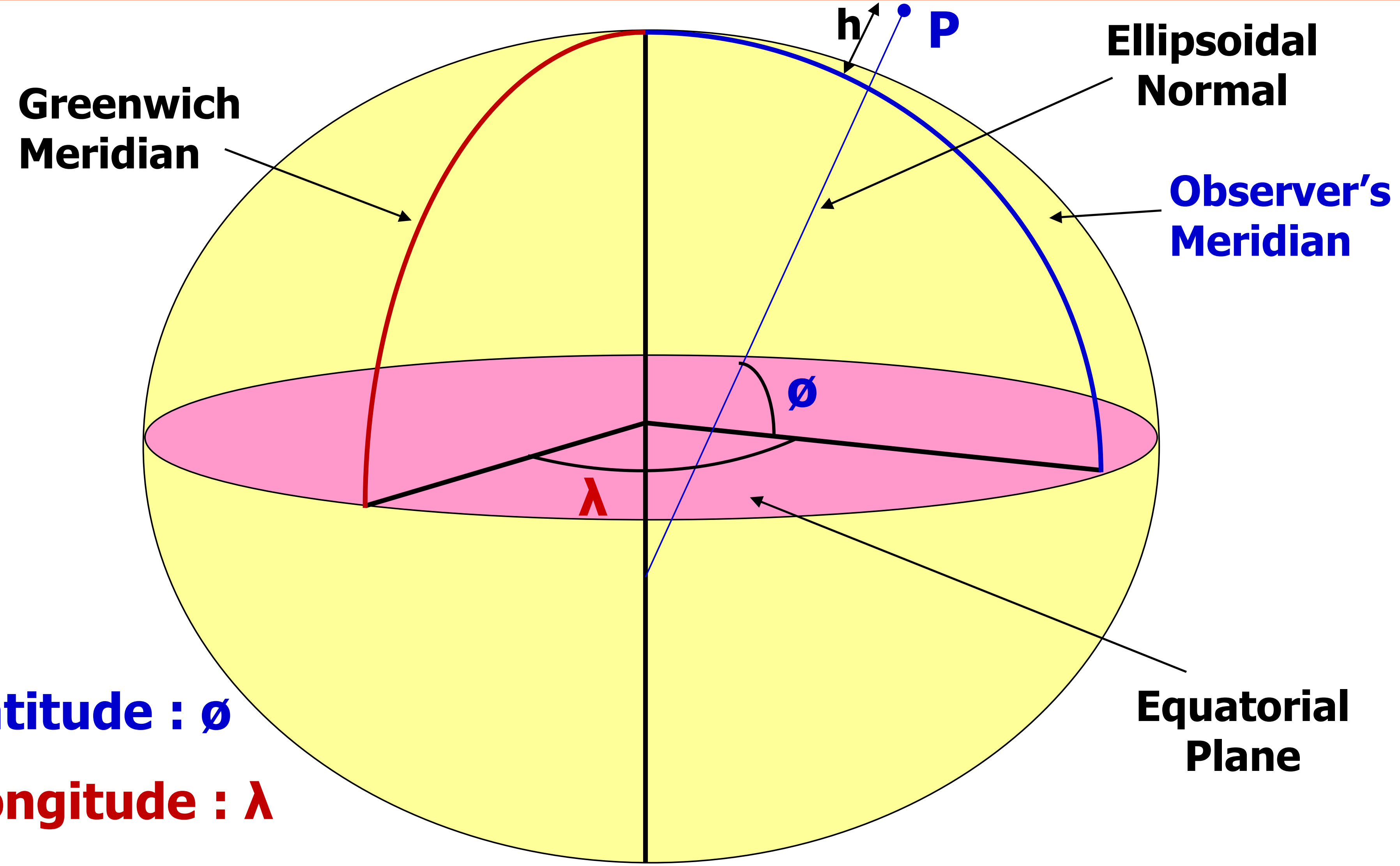
It may be defined as surface coinciding with MSL in the oceans and continuing under the land at the level to which the sea would reach if allowed to flow through frictionless channels.

Representation of Point

- Horizontal : Ellipsoid
- Vertical : Geoid

H = Orthometric Height
h = Ellipsoidal Height
N = Geoidal Undulation





Latitude : ø

Longitude : λ

Ellipsoidal Height : h

Latitude, Longitude and Ellipsoidal Height

- **Latitude:** The angle subtended at Equatorial Plane by the Ellipsoidal Normal through the observer's point.

- **Longitude**: The angle between Observer's Meridian Plane and Greenwich Meridian Plane.

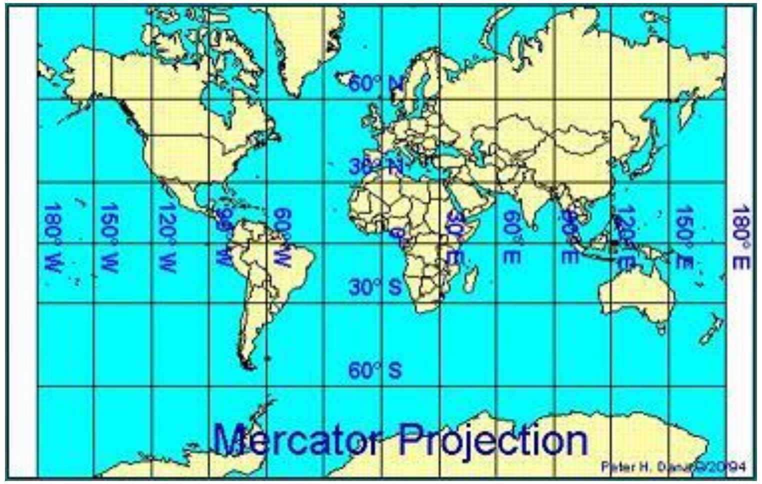
- **Ellipsoidal Height:** The height above the surface of ellipsoid, measured along the ellipsoidal normal.

Map Projection

EARTH : 3D

Projection

MAP : 2D



Lat, Long, Ht

or

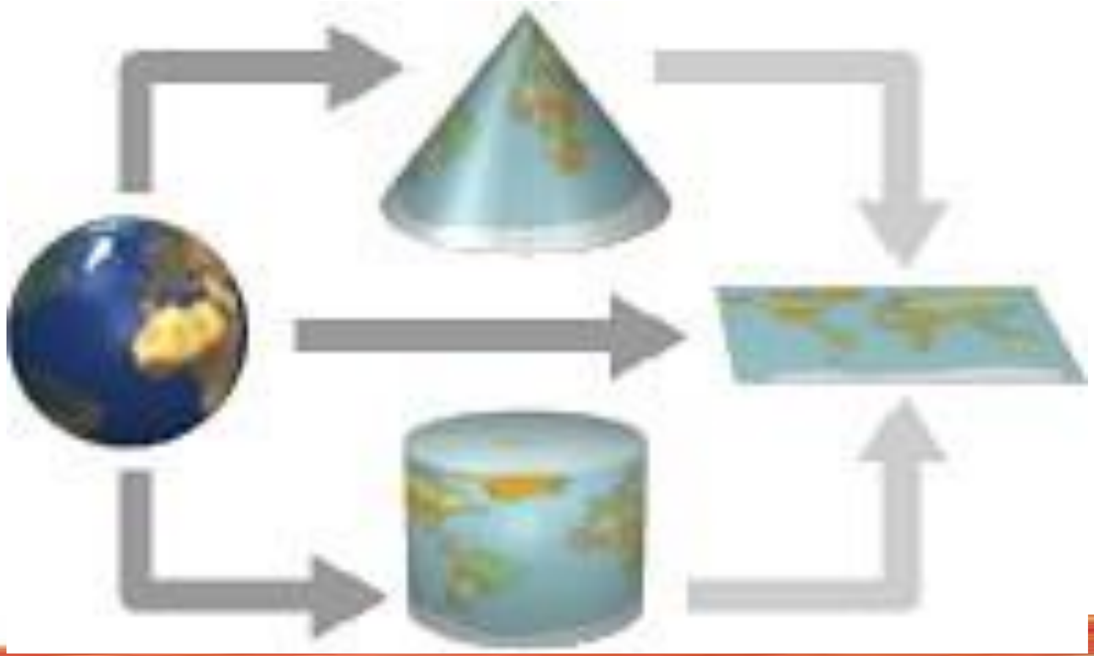
X, Y, Z

x , y

Map Projection

Transformation of Three Dimensional Space onto a two dimensional map

A systematic arrangement of intersecting lines on a plane that represent and have a one to one correspondence to the meridians and parallels on the datum surface



Types of Projections

- **Equal Area**: Maintain equal relative sizes. Used for maps that show distributions or other phenomena where showing area accurately is important. Examples: Lambart Azimuthal Equal Area, The Albert Equal Area Conic.

- **Conformal**: Maintain angular relationships and accurate shapes over small areas. Used where angular relationships are important such as for navigation and meteorological charts. Examples: Mercator, Lambert Conformal Conic

- **Equidistant**: Maintains accurate distance from center of the projection or along given lines. Used for radio and seismic mapping, and for navigation. Examples: Equidistant conic, Equirectangular.

- **Azimuthal or Zenithal**: Maintains accurate directions (and therefore angular relationships) from a given central point. Used for aeronautical charts and other maps where directional relational are important. Examples: Gnomonic projection

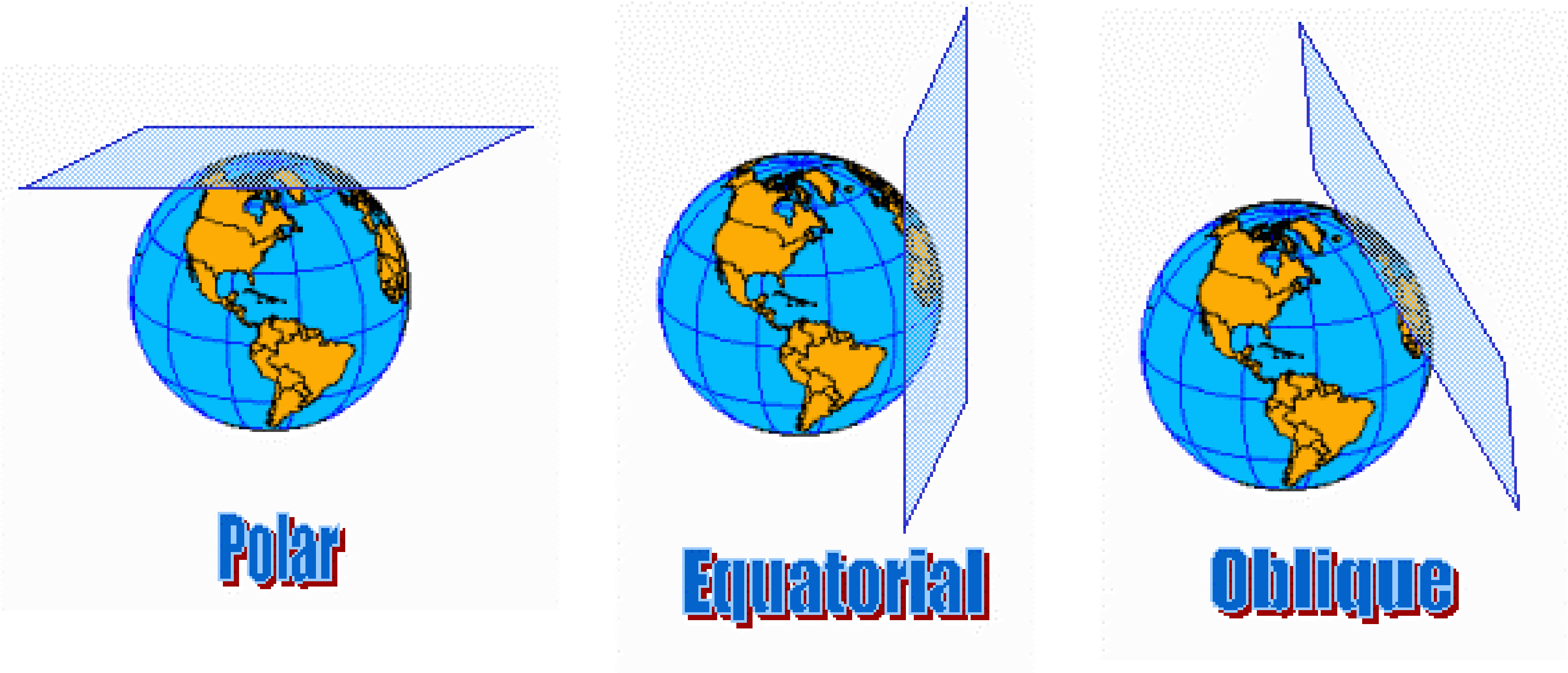
Classification

- Map projections can be classified based on their method of construction.
- There are many surfaces which are not plane but which can be created by rolling a plane surface.
- Such types of surfaces are called developing surfaces.
- Cylinder and cone are such surfaces.
- A map projection can be created by placing such surface on a globe, projecting the features from globe to the surface and then un-wrapping the surface to make a plane map.

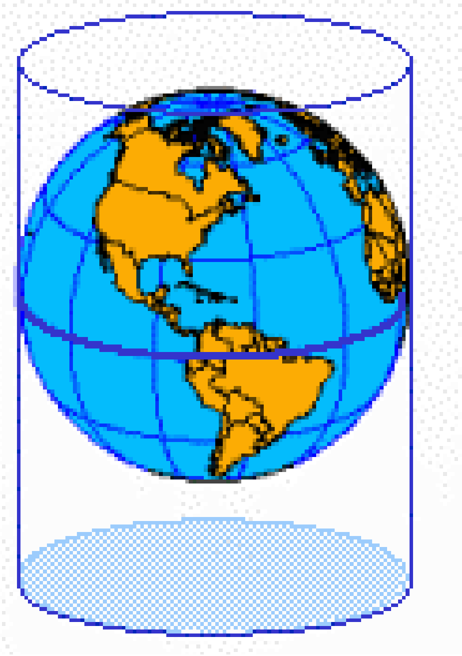
Classification

- **A) Based on Extrinsic property**
- Nature:
  - ✓ Plane, Cone, Cylinder
- Coincidence:
  - ✓ Tangent, Secant, Polysuperficial
- Position:
  - ✓ Normal, Transverse, Oblique

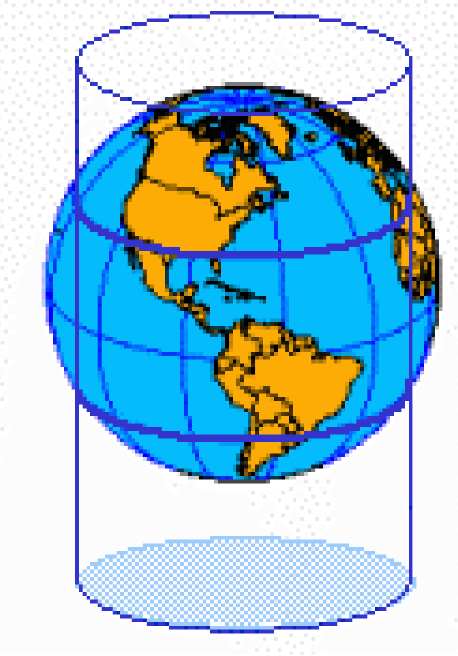
Azimuthal Projections



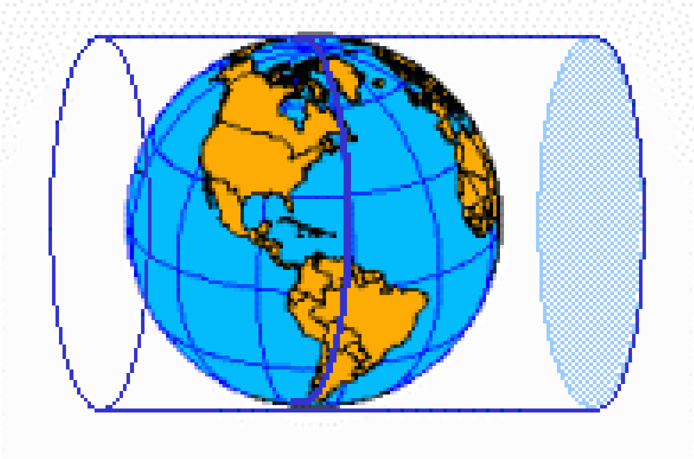
Cylindrical Projections



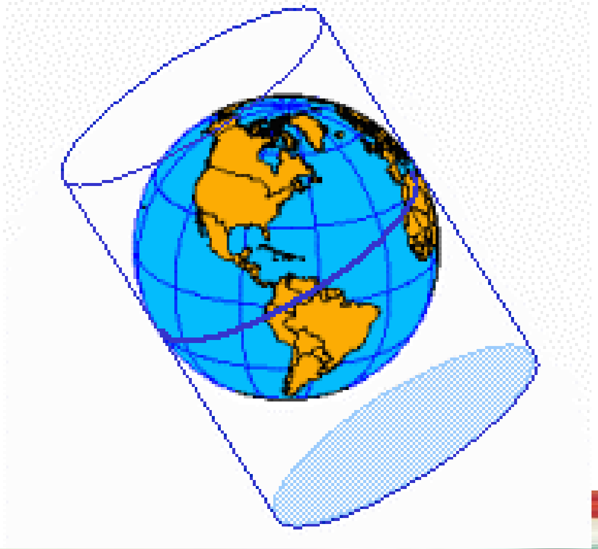
Tangent



Secant

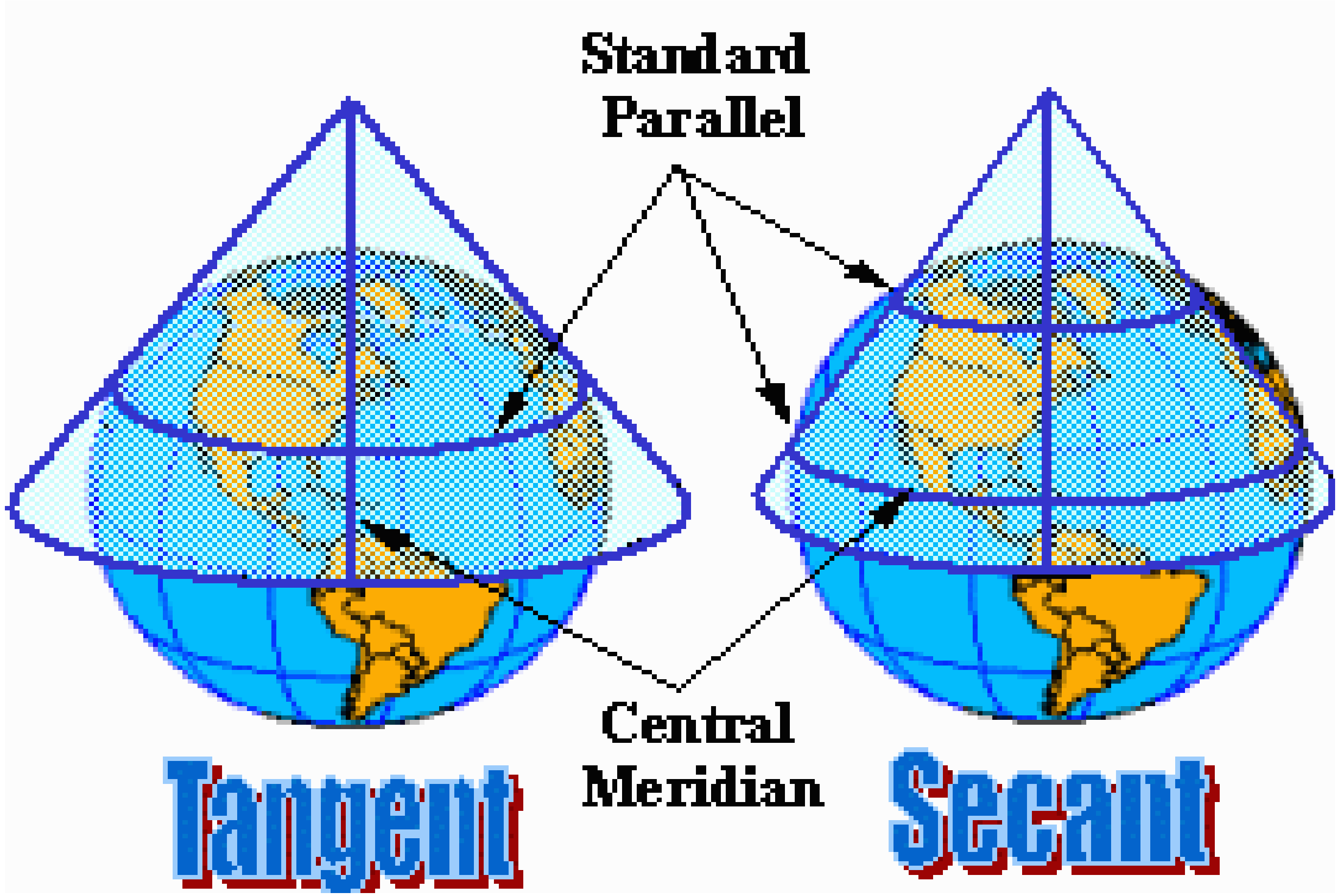


Transverse



Oblique

Conic Projections



Intrinsic Property

- Many properties can be measured on the earth's surface. Some of these properties are:

  - ✓ Area (Correct Earth surface area)
  - ✓ Shape (Local angles are shown correctly)
  - ✓ Direction (All directions are shown correctly relative to the center)
  - ✓ Distance (Preserved along particular lines)

- Map projections can be constructed to preserve one or some of these properties, though not all of them simultaneously.

- Each projection preserves or compromises or approximates basic metric properties in different ways.

- The degree and kinds of distortion vary with the projection used. Some projections are suited for mapping large areas that are mainly north-south in extent , others for large areas that are mainly east-west in extent.

Classification

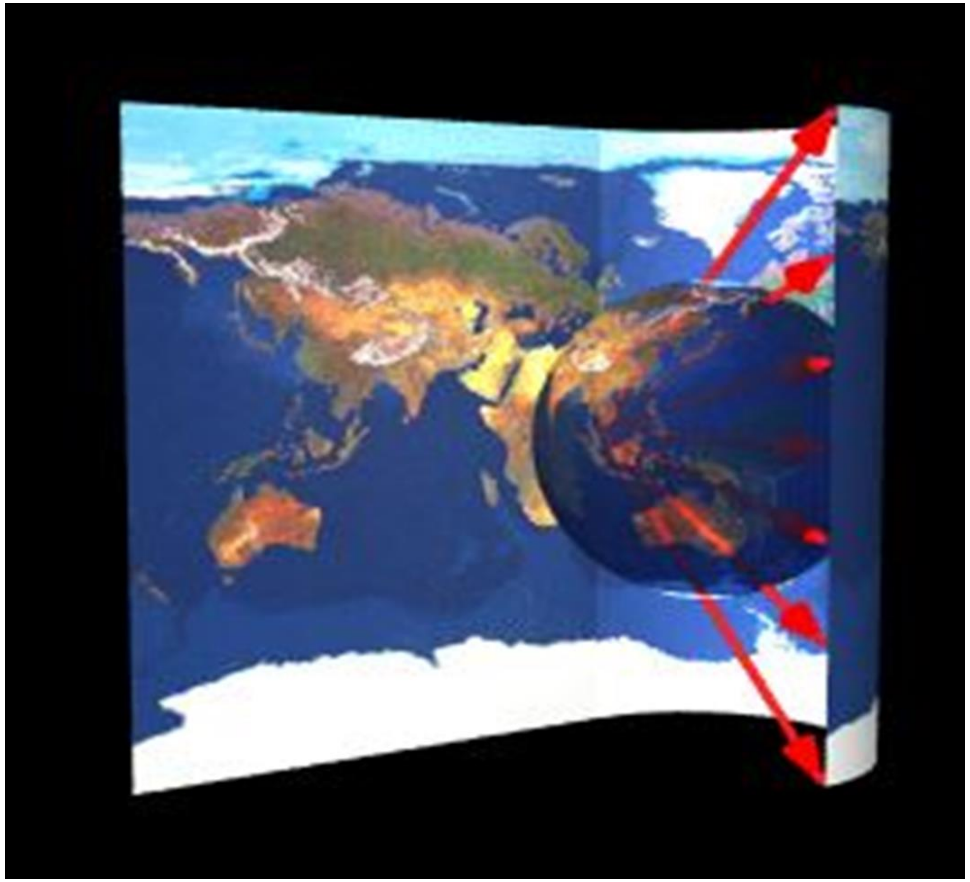
- **B) Based on Intrinsic Property**
- **Property of Projection:**
  - ✓ Equidistant
  - ✓ Conformal or Orthomorphic
  - ✓ Equivalent or Equal area
- **Generation:**
  - ✓ Geometric, Semi Geometric, Mathematical

Various Map Projections

Cylindrical Map Projections

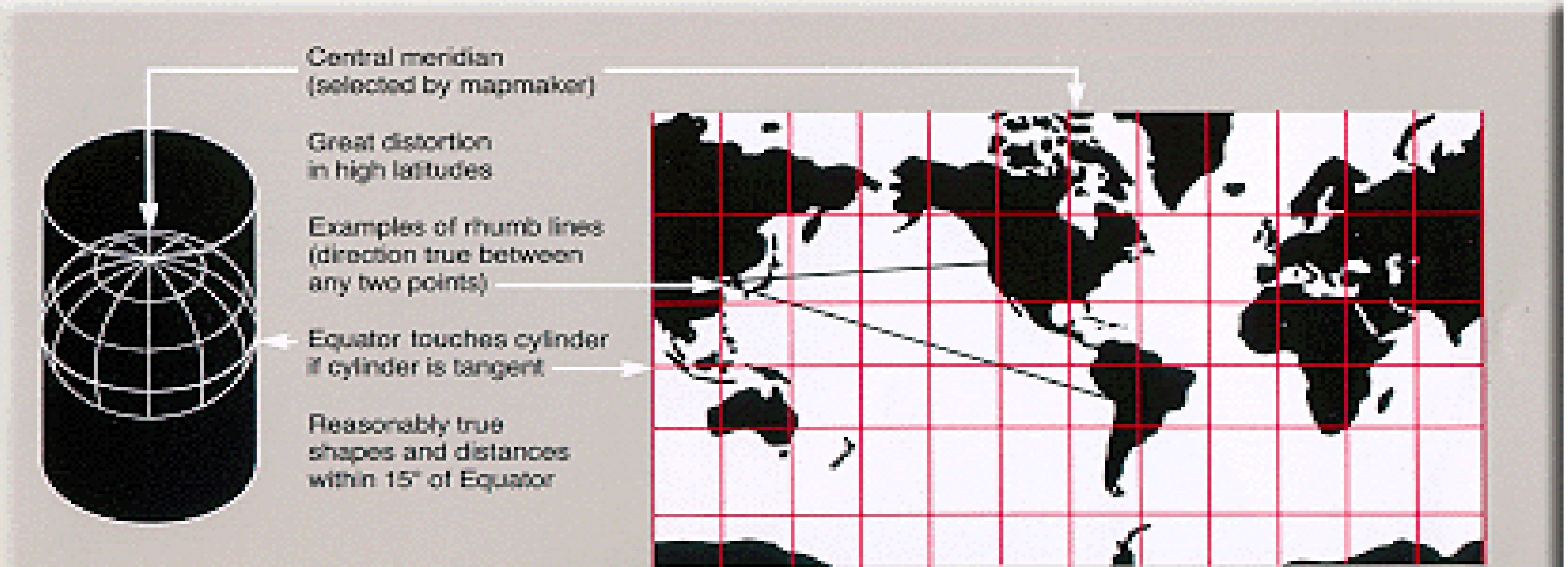
- Cylindrical map projections are made by projecting from the globe onto the surface of an enclosing cylinder, and then unwrapping the cylinder to make a flat surface

  - Mercator
  - Transverse Mercator



Mercator Projection

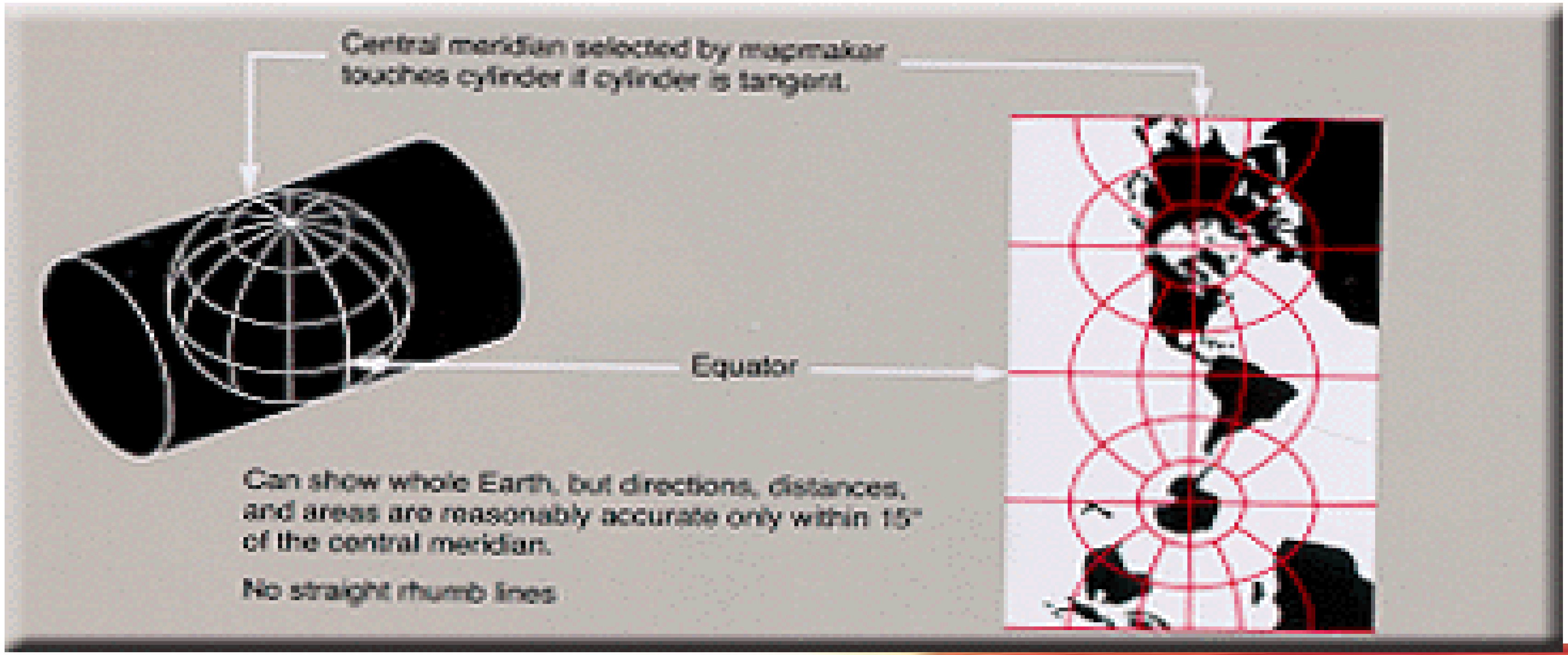
- Cylindrical, Conformal
- Meridians are equally spaced straight lines
- Parallels are unequally spaced straight lines
- Scale is true along the equator
- Great distortion of area in polar region
- Used for navigation



REGULAR CYLINDRICAL PROJECTION: THE MERCATOR

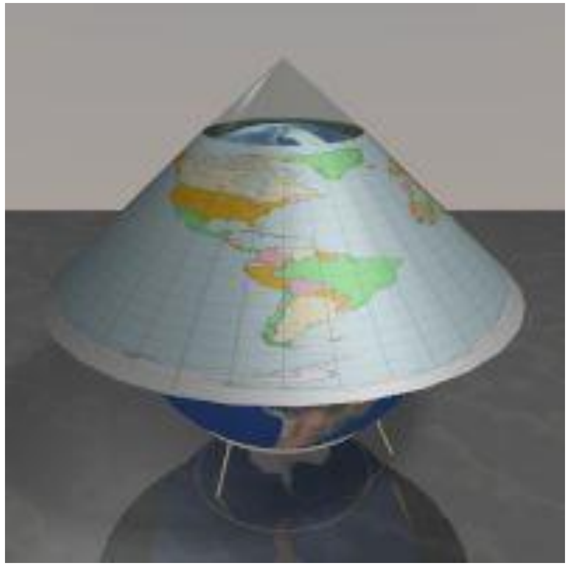
Transverse Mercator Projection

- Cylindrical (Transverse)
- Conformal
- Central meridian and equator are straight lines
- Other meridians and parallels are complex curves
- For areas with larger north-south extent than east-west extent



TRANSVERSE CYLINDRICAL PROJECTION: THE TRANSVERSE MERCATOR

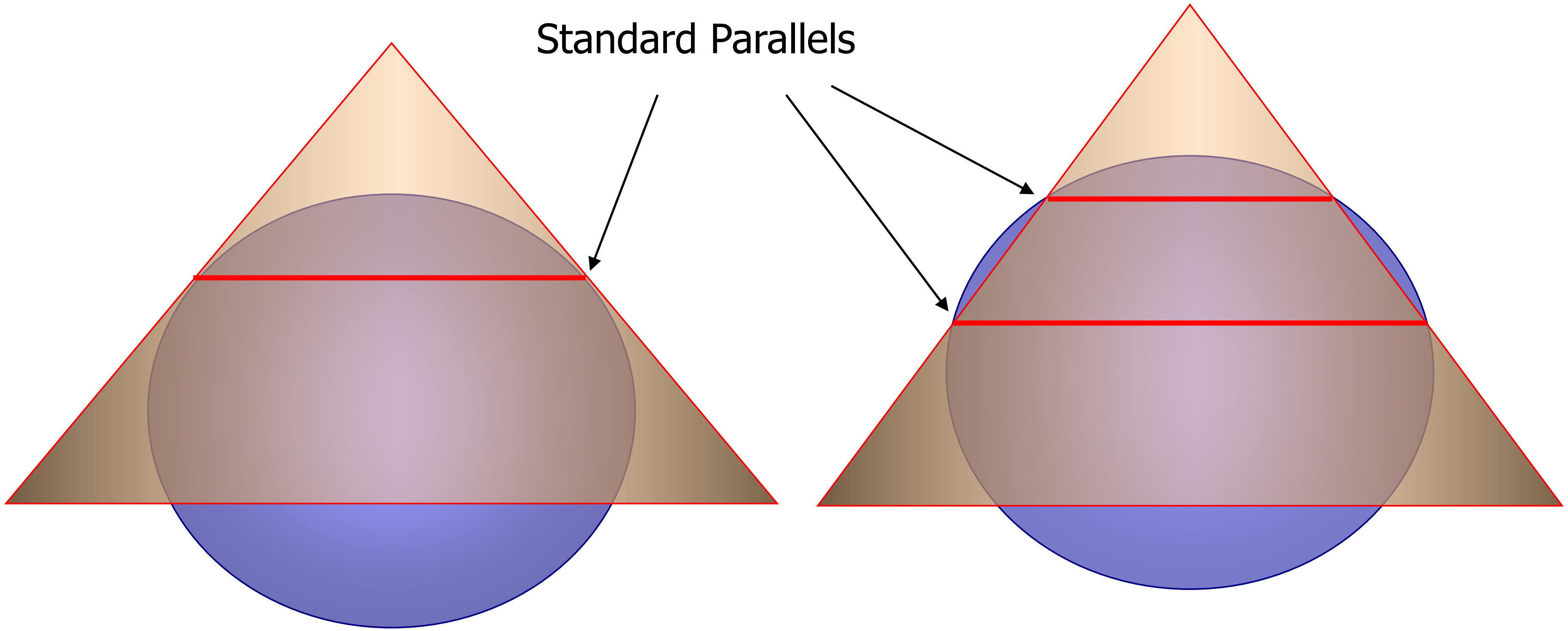
Conic Projections



- For a conic projection, the projection surface is cone shaped
- Locations are projected onto the surface of the cone which is then unwrapped and laid flat

Lambert Conformal Conic Projection

- Conical, Conformal
- Parallels are concentric arcs
- Meridians are straight lines cutting parallels at right angles.
- Scale is true along two standard parallels, normally, or along just one.
- It projects a great circle as a straight line
- Used for maps of countries and regions with predominant east west expanse
- Used for plane coordinate system in USA



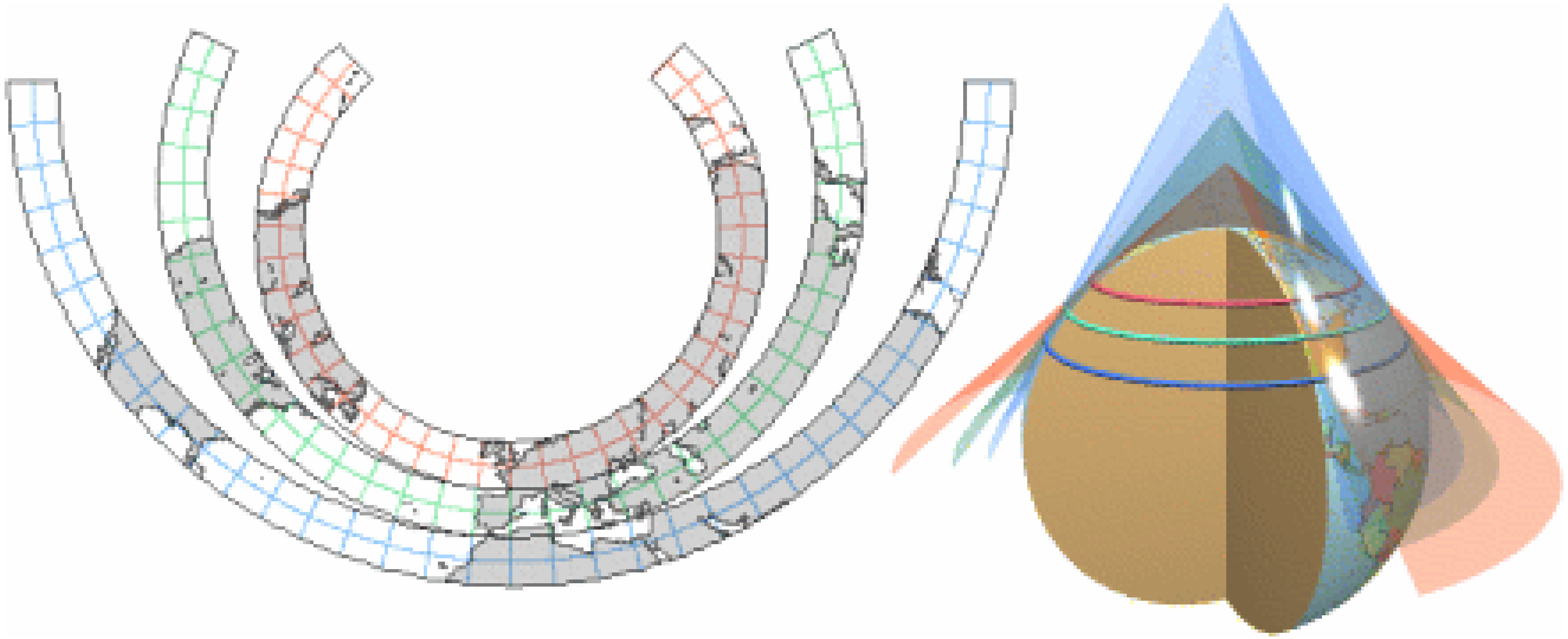
1 Standard Parallel

2 Standard Parallels

LCC PROJECTION

Polyconic Projection

- In this projection all parallels are projected without any distortion
- Scale is exact along each parallel and central meridian
- Parallels are arcs of circles but are not concentric.
- It is neither conformal nor equal area.
- Central meridian and equator are straight lines; all other meridians are curves.
- Central Meridian cuts all parallels at 90 degrees
- Free of distortion only along the central meridian.
- Used in India for all topographical mapping on 1:250,000 and larger scales.



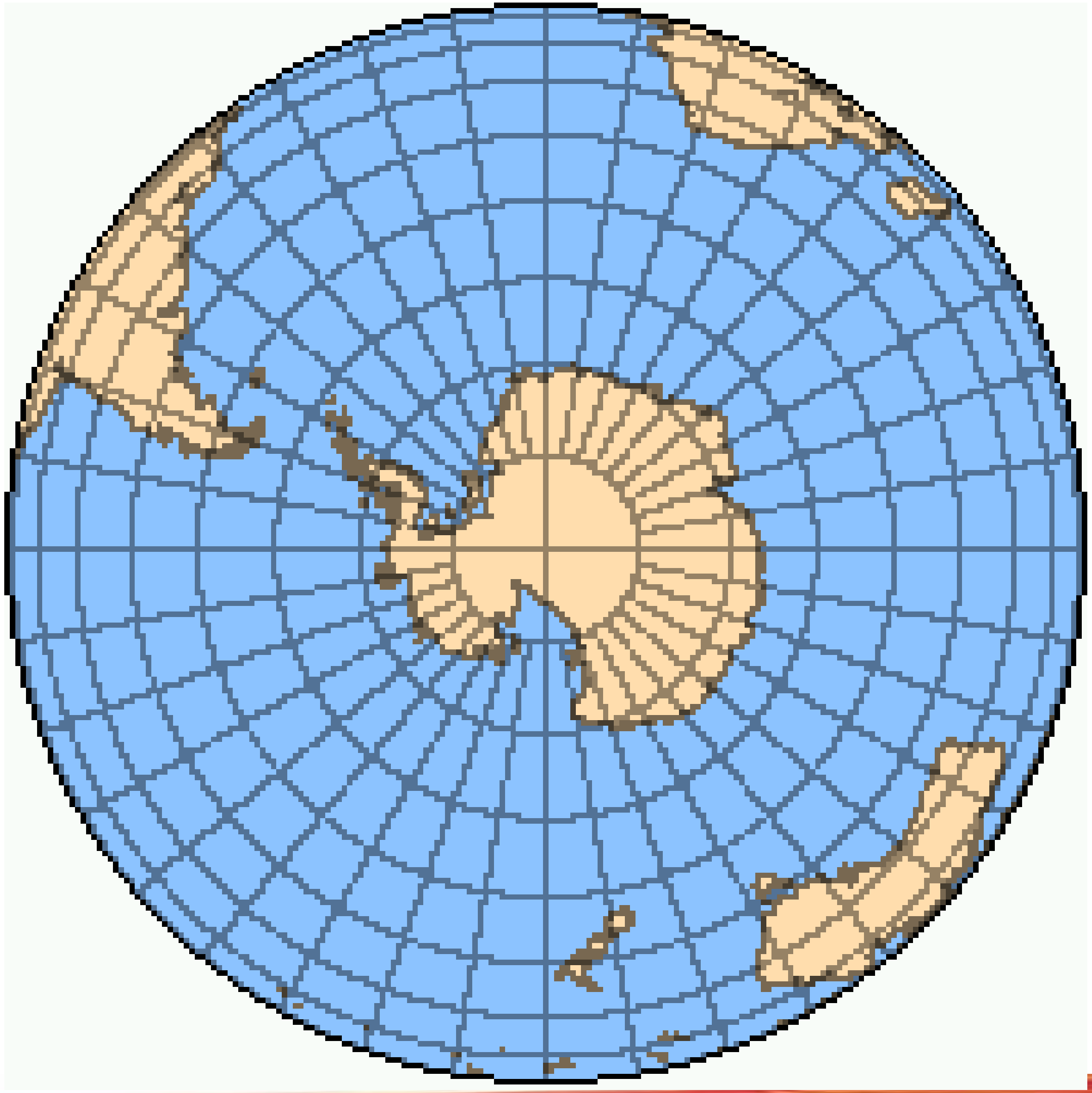
Three partial equidistant conic maps, each based on a different standard parallel, therefore wrapped on a different tangent cone (shown on the right with a quarter removed plus tangency parallels). When the number of cones increases to infinity, each strip infinitesimally narrow, the result is a continuous polyconic projection

Azimuthal Projections

- For an azimuthal, or planar projection, locations are projected forward onto a flat plane.
- The normal aspect for these projections is the North or South Pole.

Universal Polar Stereographic (UPS)

- Defined above 84 degrees north latitude and below 80 degree south
- Conformal
- Meridians are straight lines
- Parallels are circles
- Used in conformal mapping of polar regions

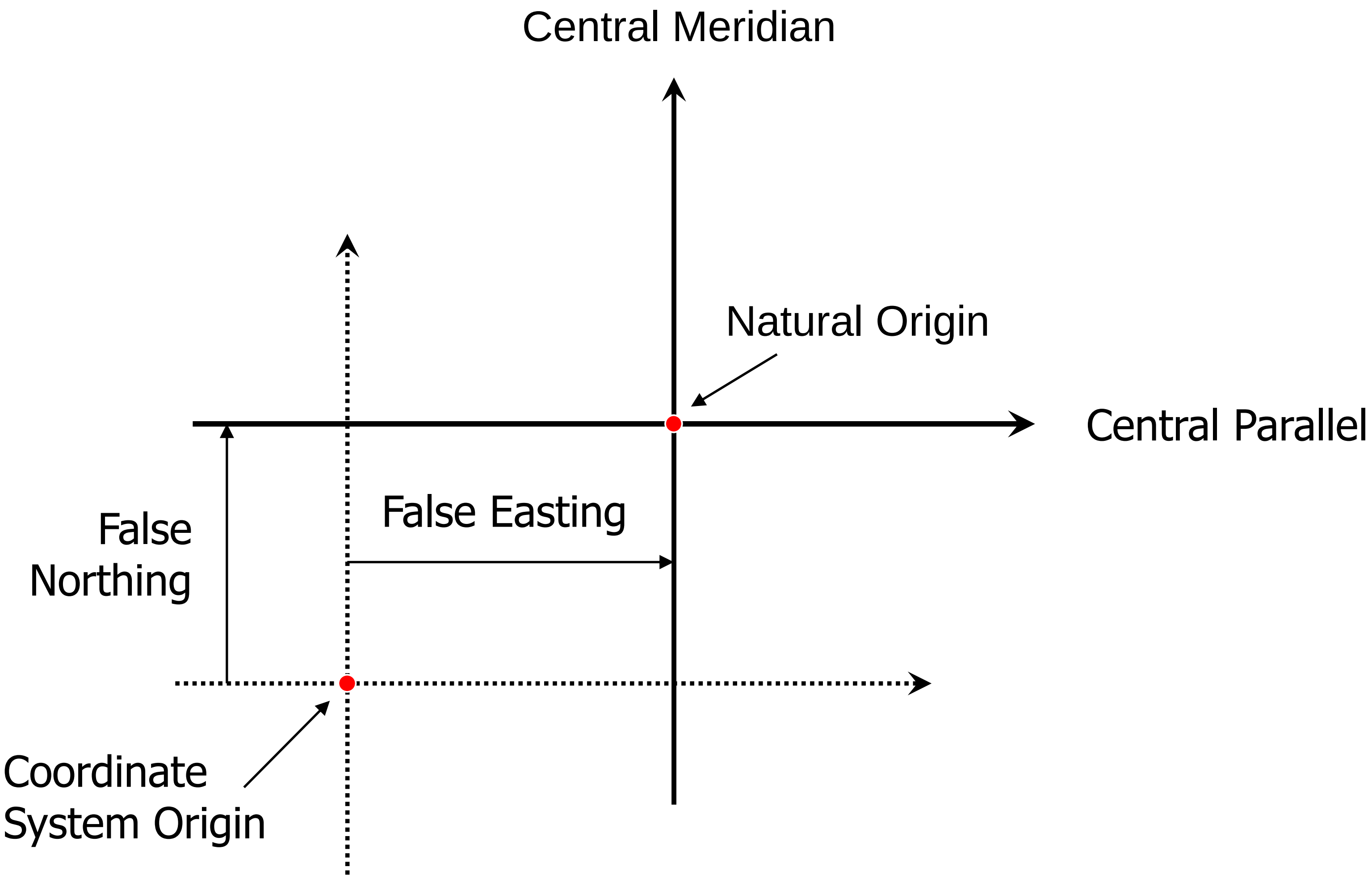


Grids

- Rectangular grids have been developed for the use of Surveyors.
- Each point can be designated merely by its (x , y) co-ordinates.
- Grid systems are normally divided into zones so that distortion and variation of scale within any one zone are kept small.
- The UTM grid

False Northing and False Easting

- Calculating coordinates is easier if negative number are n't involved.
- Example : Universal Transverse Mercator coordinates
- Expressed in coordinate units, not degrees.

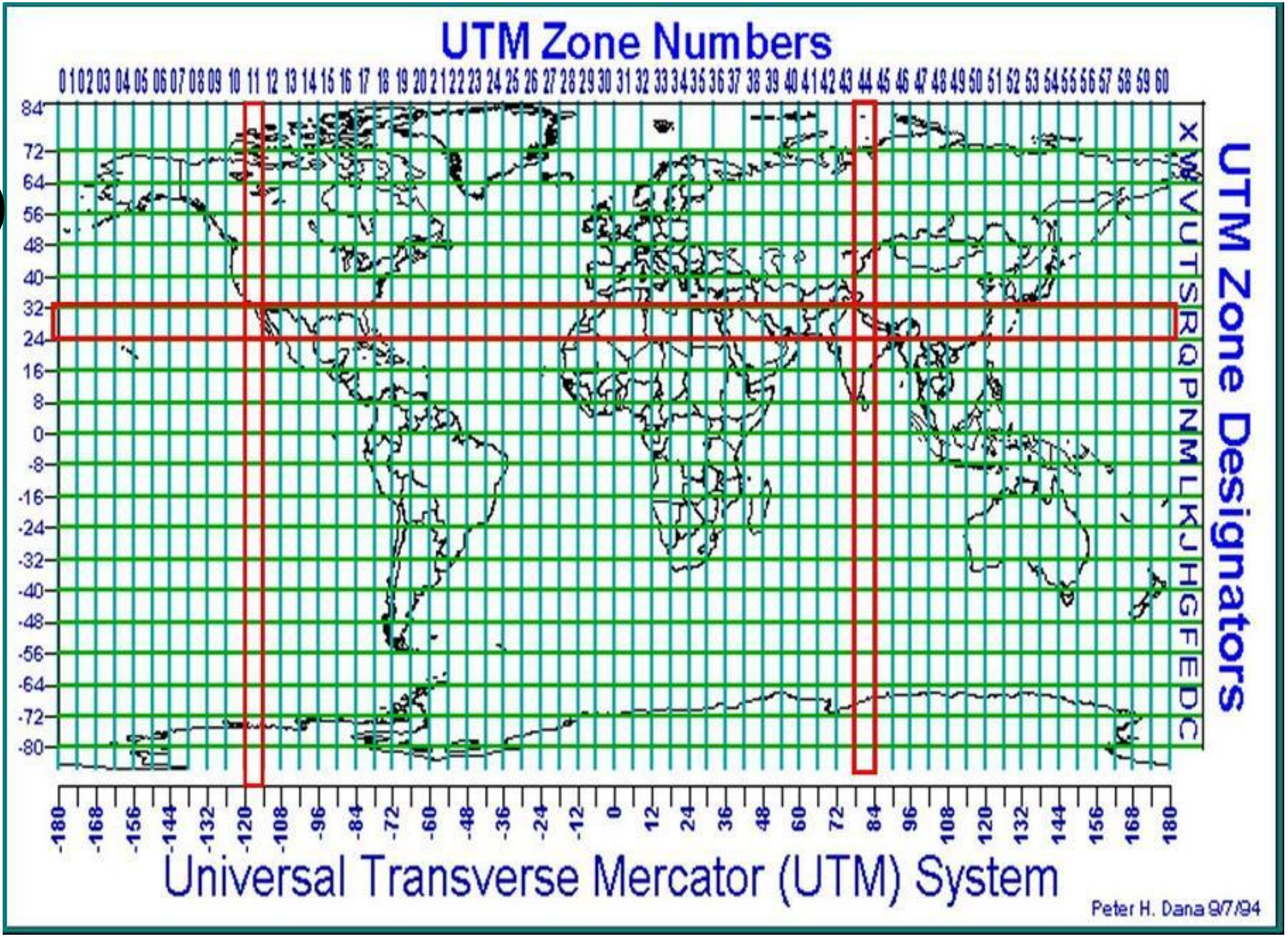


SPECIFYING AN ORIGIN SHIFT:

THE FALSE EASTING AND FALSE NORTHING

Universal Transverse Mercator (UTM)

- Particular case of Transverse Mercator Projection.
- The earth between latitudes 84° N and 80° S, is divided into 60, 6° wide areas
- Latitude origin – the equator



Choosing a map Projection

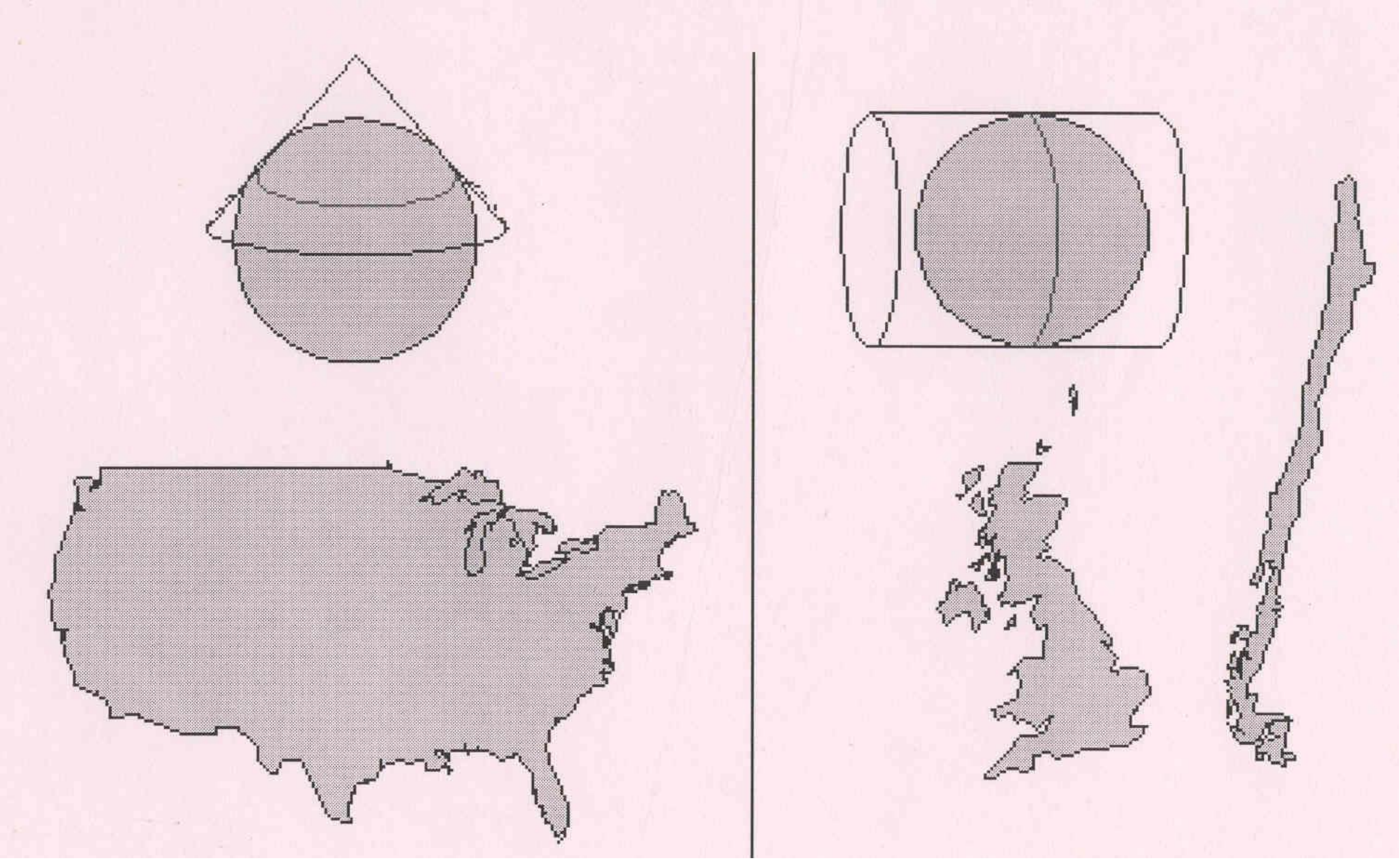
- The choice of map projection is made to give the most accurate possible representation of the geographic information, given that some distortion is inevitable. The choice depends on:

✓ The location

✓ Shape

✓ Size of the region to be mapped

✓ The theme or purpose of the map



Projection Parameters

- To define the coordinate system completely, it is not sufficient simply to name the kind of projection used, it is also necessary to specify the projection parameters.
- It is important to know the Projection and Projection Parameters used in map / imageries.
- Sometimes it is required to superimpose one map or image on another map. If map and Imagery have different projection parameters, the details will not match if they are superimposed.
- The set of parameters required depends on the kind of projection.

Projection Parameters contd.

- The central meridian of the projection for cylindrical, where it touches the ellipsoid surface.
- The standard parallel(s) for conic projections.
- The false easting and false northing
- The units
- Reference System / Ellipsoid

New Mapping Policy

- Open Series Maps
- Defense Series Maps
- Switchover from Everest coordinate system to Geocentric coordinate system, ITRF, GRS 80 etc
- OSM Series
  - ✓ Polyconic / Everest ⟶ UTM/WGS-84
- DSM Series
  - ✓ Polyconic / Everest ⟶ LCC/WGS-84

Conclusions

- We need to project geospatial data for any analysis
- Make it possible to use data from different sources
- Several projections to choose from
- Projections inevitably distorts at least one property
- Can choose suitable map projection
- Can control Scale Error

Thank You

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