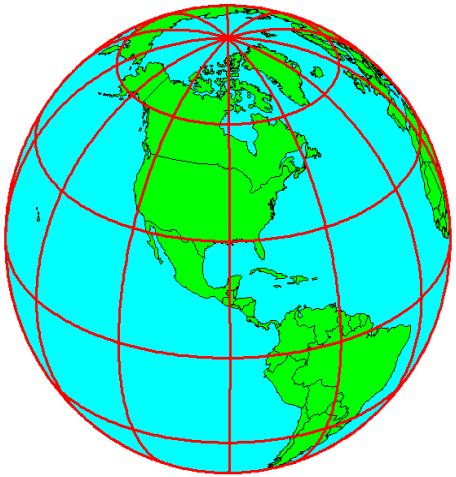
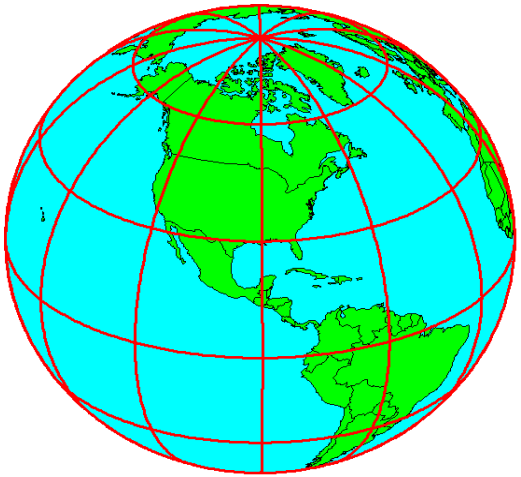
Coordinate Systems

We think of the earth as a sphere



It is actually a spheroid (ellipsoid), slightly larger in radius at the equator than at the poles



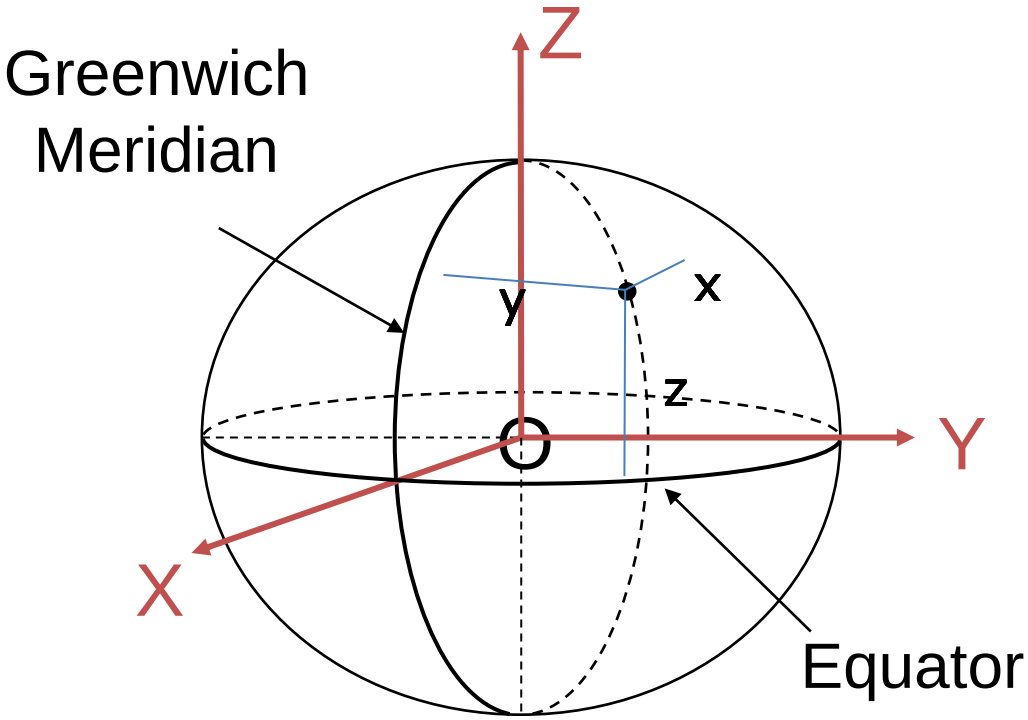
Shape of the Earth

Location on earth is defined by coordinates

Types of Coordinate Systems to define location

- (1) Cartesian coordinates (x,y,z)- used by GPS
- (2) Geographic coordinates (ϕ, λ, h) used for mapping and ellipsoidal height determination
- (3) Projected coordinates (E, N, H) on a local area of the earth's surface. (mapping coordinates)
- H - referenced to mean sea level (geoid)
- H - known by level or elevation or orthometric height
- h - referenced to ellipsoid surface and known by ellipsoidal height

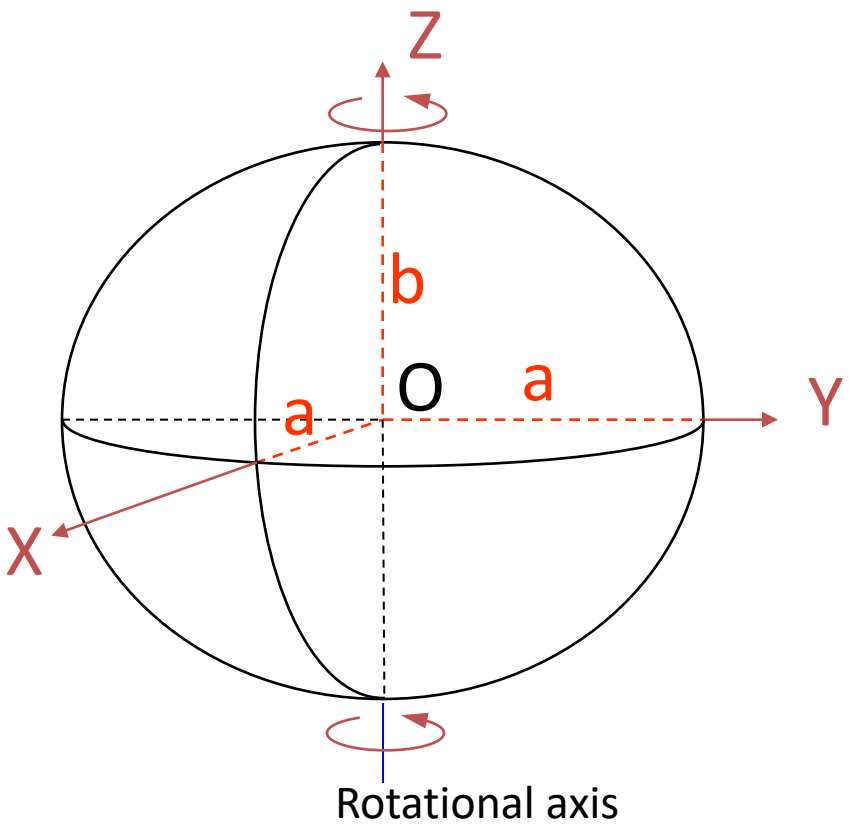
Cartesian Coordinates (x,y,z)



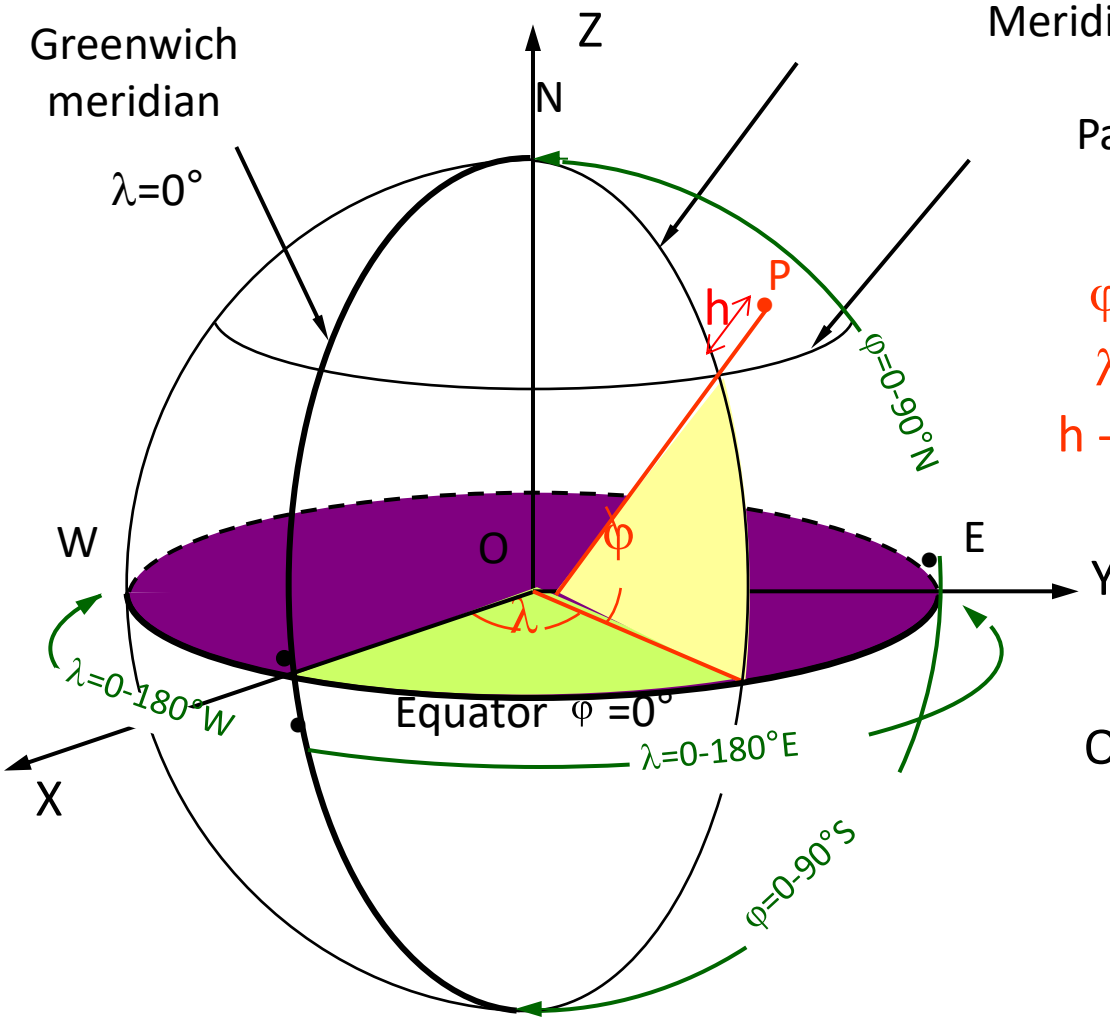
- GPS defines the Cartesian coordinates X, Y, Z .
- The Cartesian coordinate system with its origin at center of earth is known as geocentric system.
- The Z axis is defined along the earth's axis of rotation
- Plane XZ passing through Z axis and Greenwich city.
- Y axis is perpendicular to XZ plane.

Ellipsoid or Spheroid

Rotate an ellipse around an axis



Geographic Coordinates



Meridian of longitude

Parallel of latitude

φ - Geographic latitude

λ - Geographic longitude

h - Ellipsoidal height

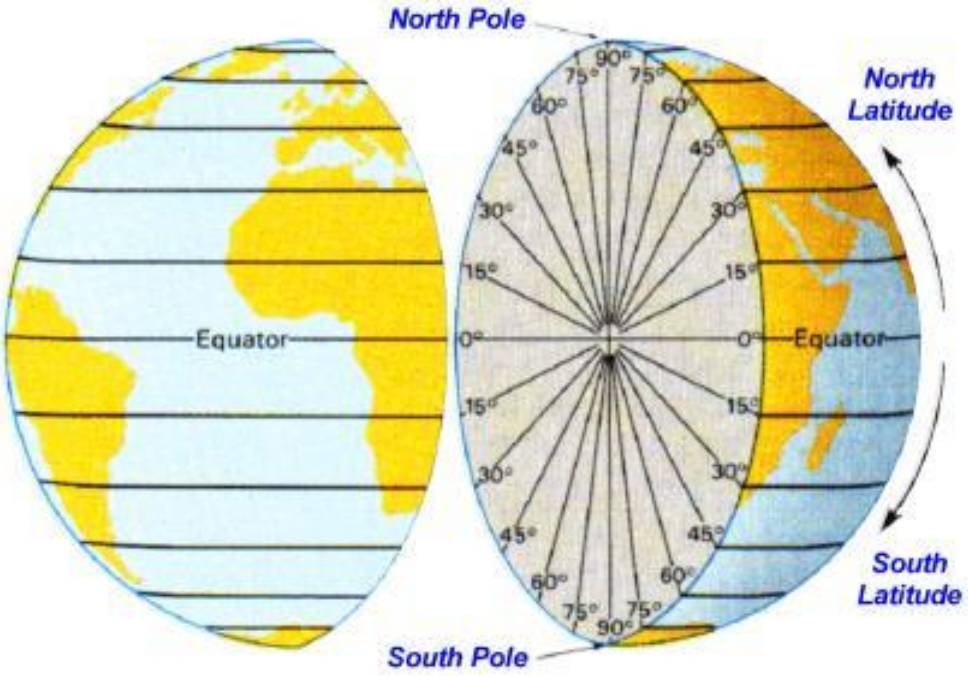
O - Geocenter

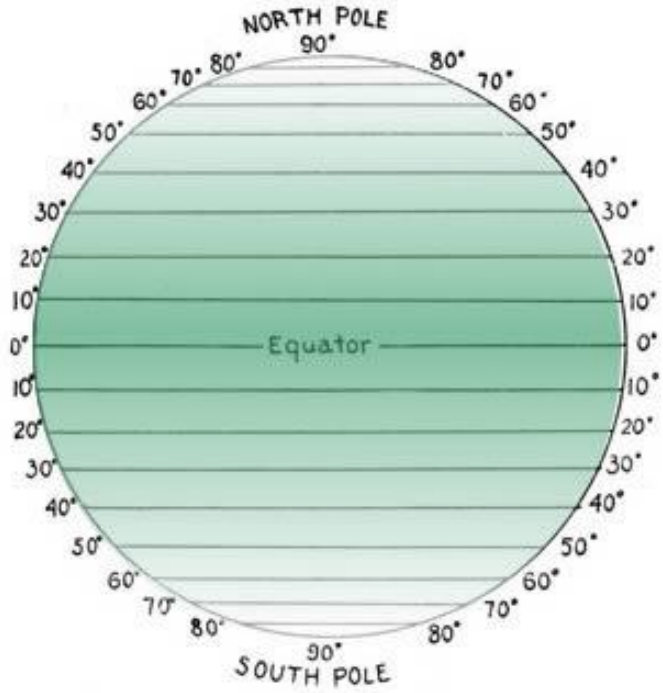
Geographic Coordinates

- GPS coordinates for different application are defined in geographic coordinates i.e. Latitude and longitude.
- Geographic coordinates for GPS are defined with respect to WGS84 ellipsoid.
- WGS84 ellipsoid is the most suitable mathematical surface to represent globally actual earth.
- WGS84 is the datum for coordinates defined by GPS.
- Latitude is angle between the normal to ellipsoid and equator. It varies between zero to 90^{o} N or zero to 90^{o} S.
- Longitude is angle measured between meridian of Greenwich and meridian of point. It varies from 0 to 180^{o} E or from 0 to 180^{o} W.

Quick Review of Latitude and Longitude

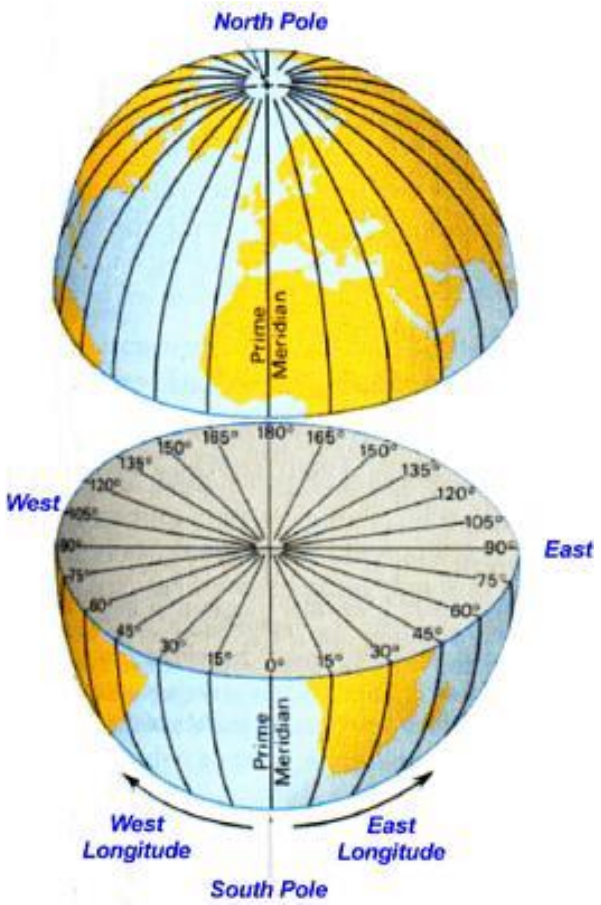
- Latitude
  - Measured in degrees North and South of the Equator.
  - Lines drawn parallel to each other running west to east.



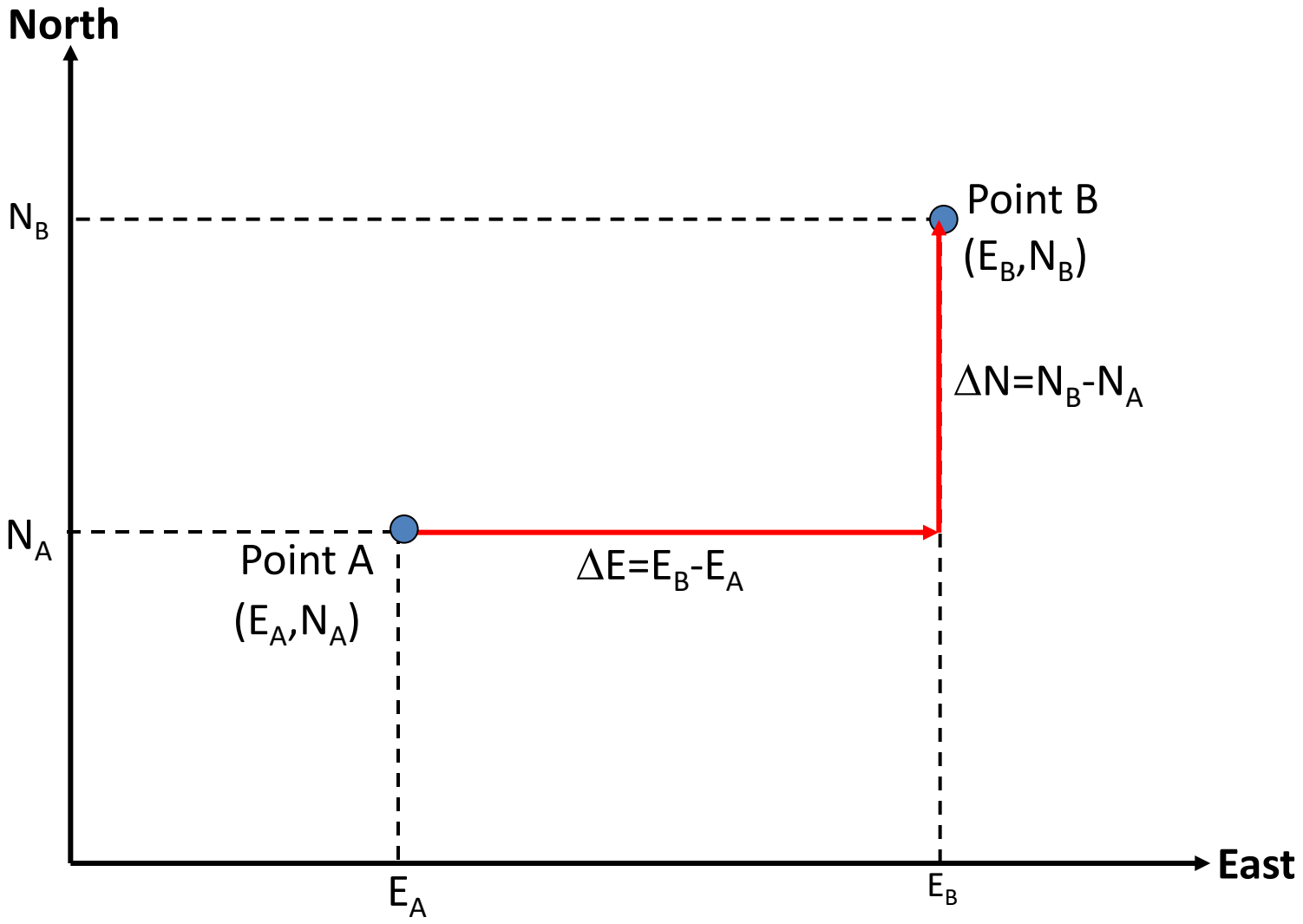


Quick Review of Latitude and Longitude

- Longitude
  - Measured in degrees East or West of the prime meridian.
  - Lines drawn running North and South.



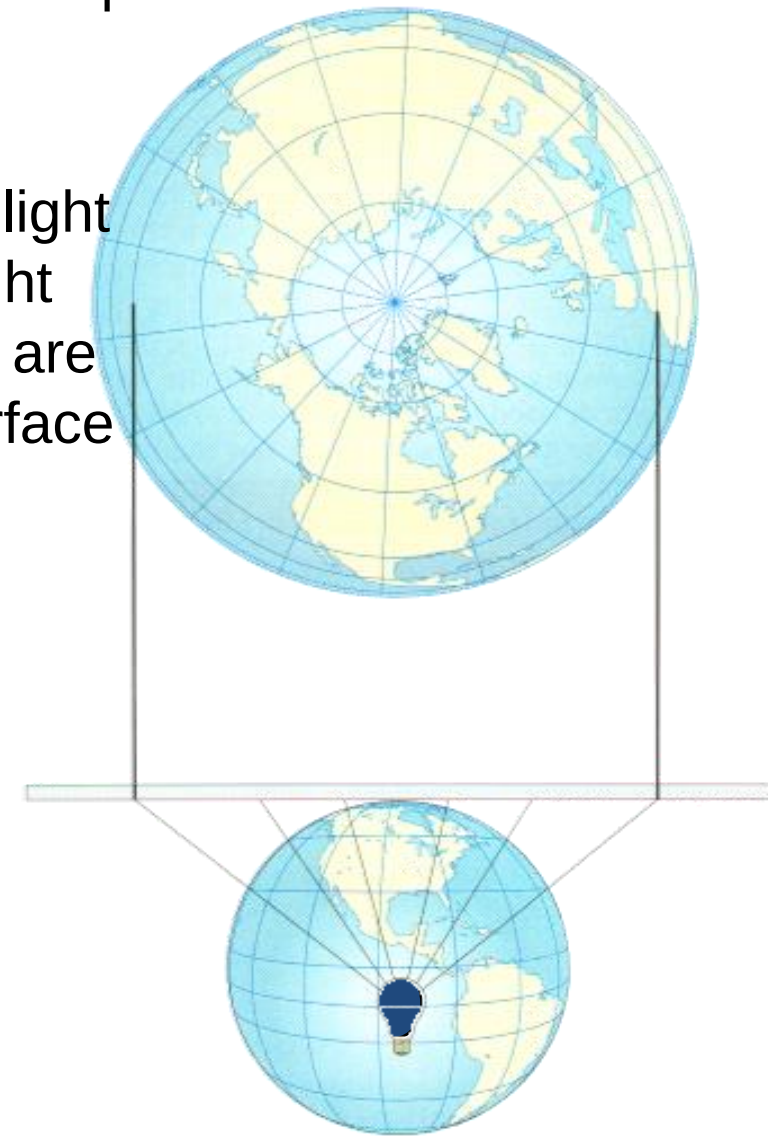
Plane coordinates



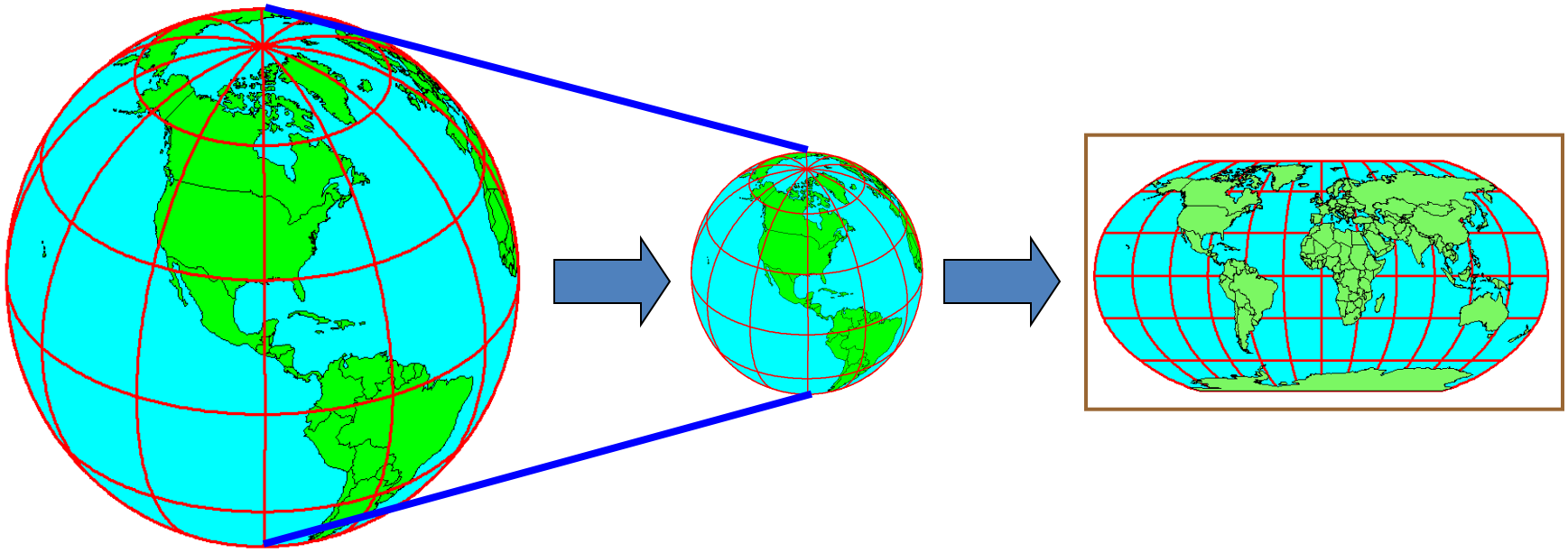
Map Projections

- The plane coordinate system or map coordinate system is the result from projection of geographic coordinates of points on earth.

- Simply one can imagine the projection as light source at center of earth and rays from light source through different features on earth are projected on plane surface of rounded surface that can converted to be plane surface.



Earth to Globe to Map



Map Scale:

Representative Fraction

$$= \frac{\text{Globe distance}}{\text{Earth distance}}$$

(e.g. 1:25000)

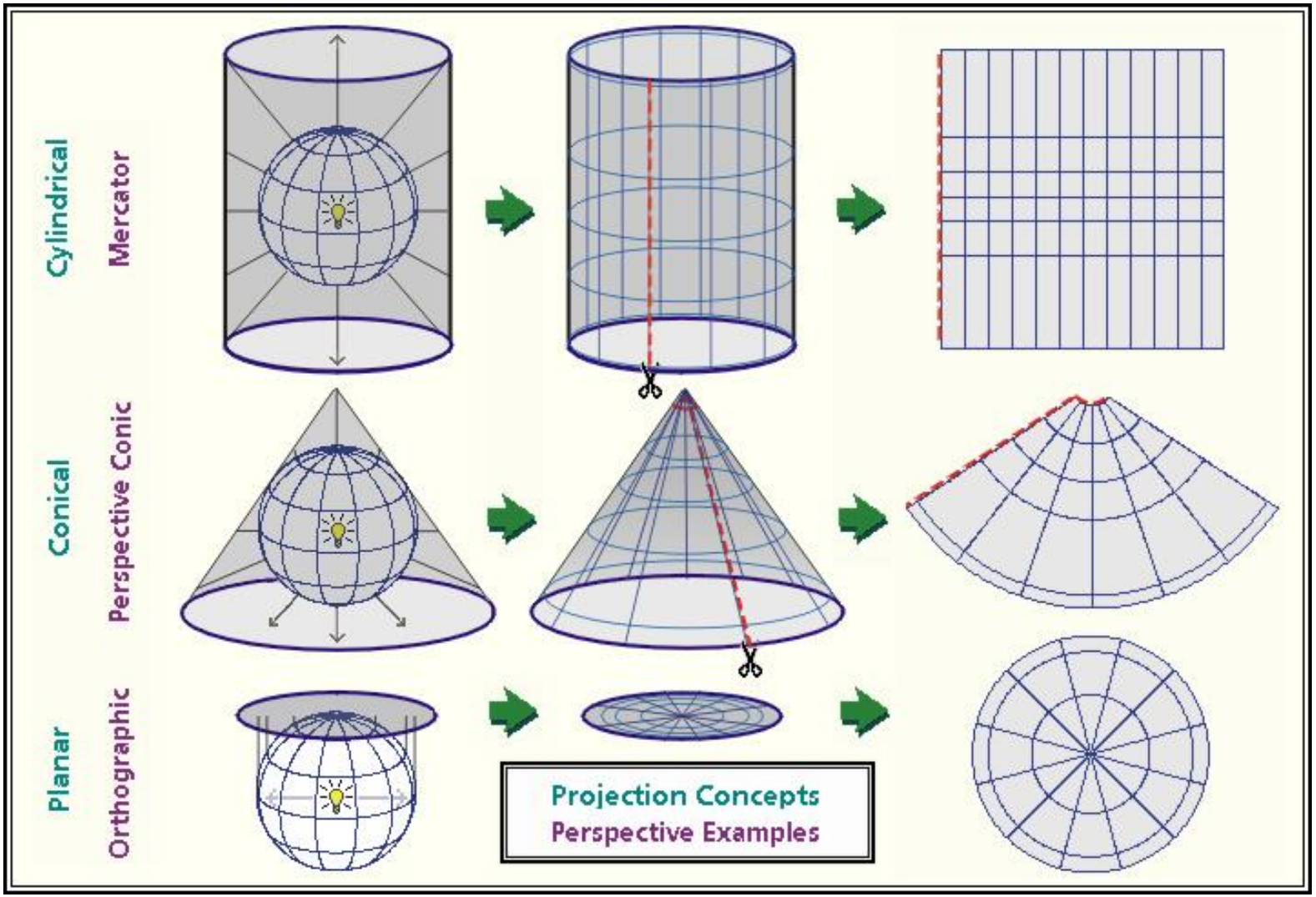
Map Projection:

Scale Factor

$$= \frac{\text{Map distance}}{\text{Globe distance}}$$

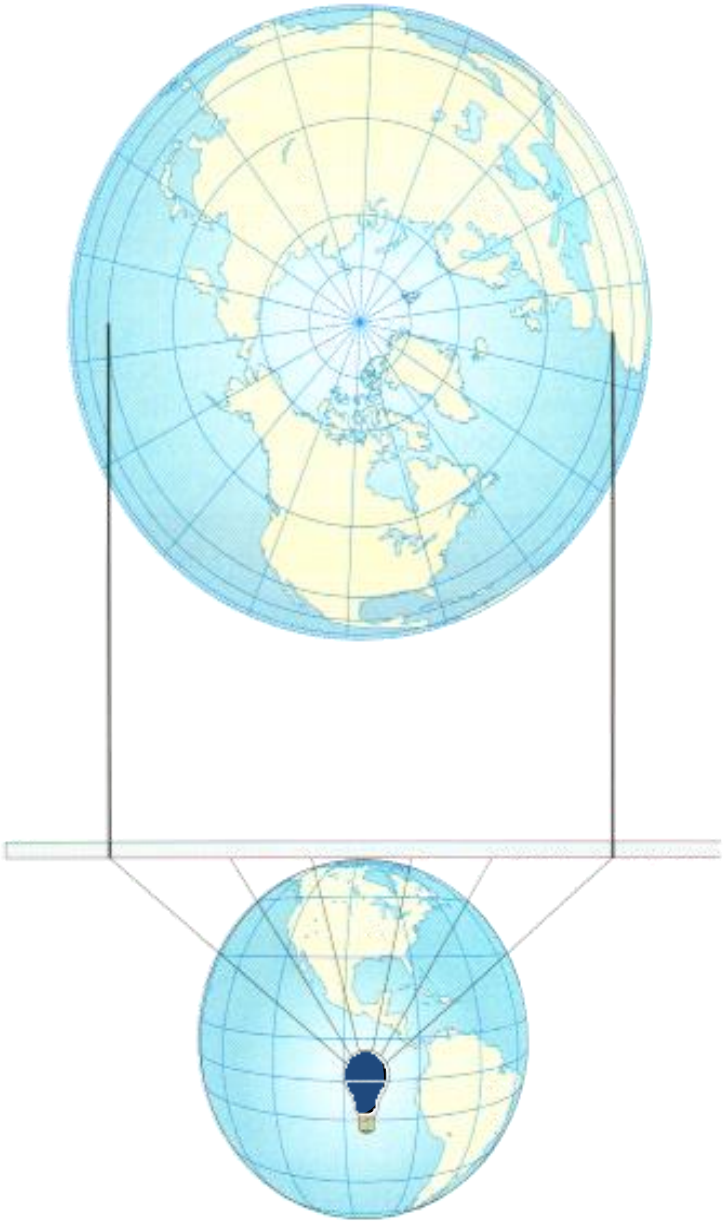
(e.g. 0.9996)

Types of Projections

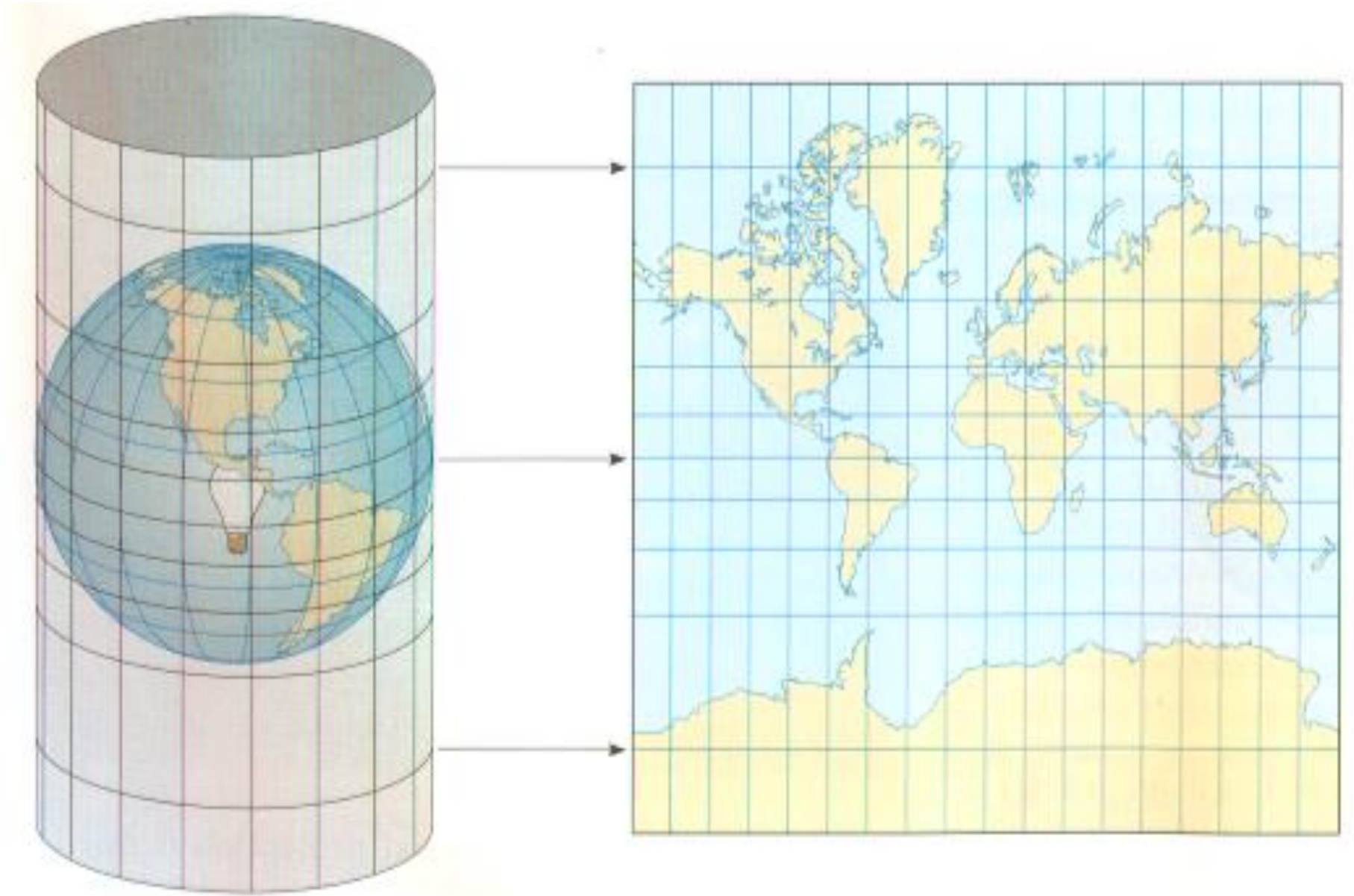


Map Projections – *Planar* or Polar

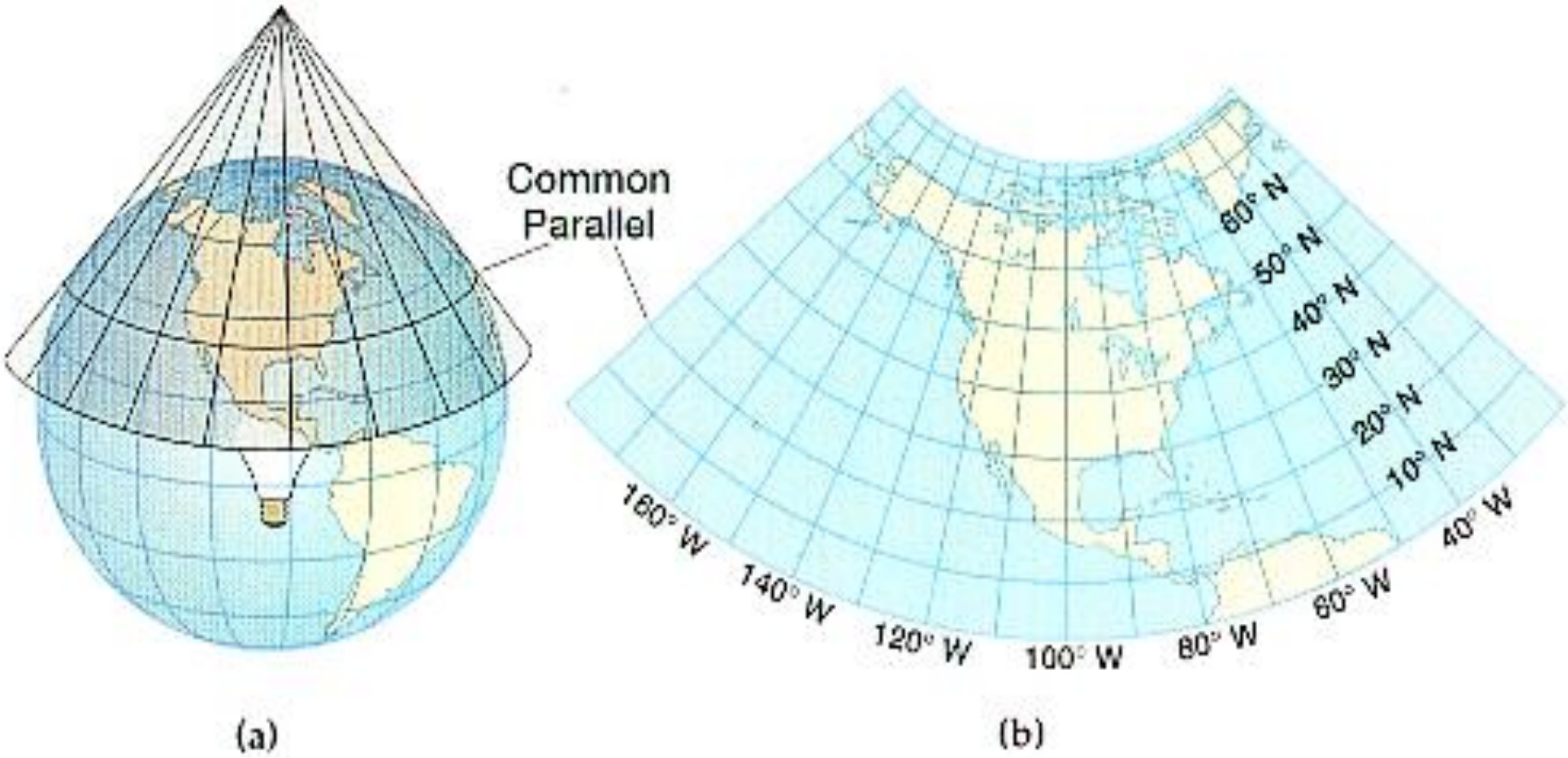
Planar or Polar Projection



Map Projections - *Cylindrical*

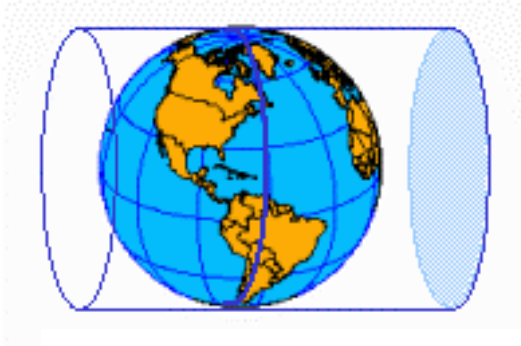


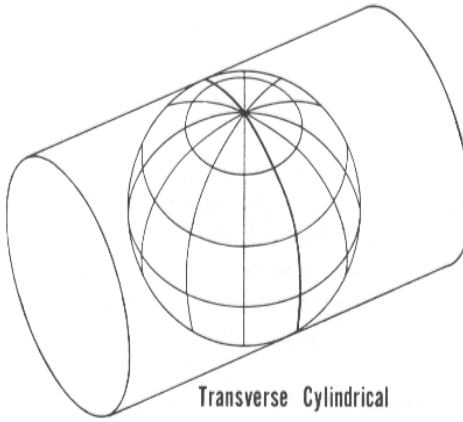
Map Projections - *Conic*

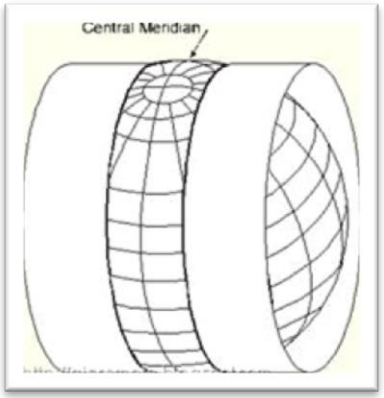


Universal Transverse Mercator UTM

- Universal Transverse Mercator UTM system is the universal map projection system.
- UTM system is used cylinder tangent to earth at different longitude.
- UTM system preserves the angles, and distorts the distances and areas (Conformal projection).
- UTM system divides the earth into zones each one with width 6 ^{o} starting from zone 1 from 180 ^{o} w to 174 ^{o} w to zone 60 from 174 ^{o} E to 180 ^{o} E.
- Reference Latitude (φ_o), is the equator
- (Xshift, Yshift) = (x_o,y_o) = (500000, 0) in the Northern Hemisphere, units are meters



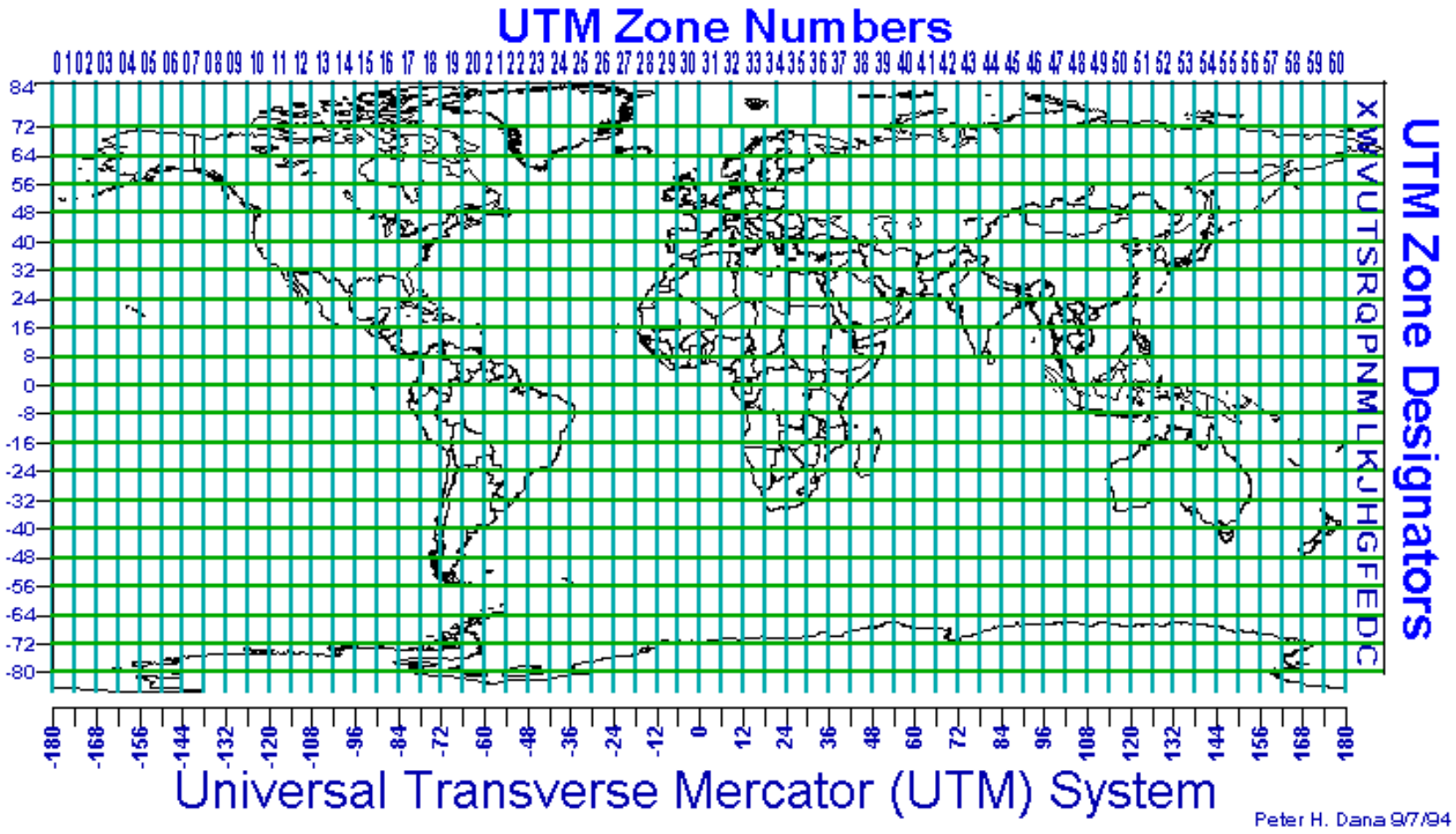




UTM projection

- Scale distortion is 0.9996 along the central meridian of a zone
- There is no scale distortion along the standard meridians
- Scale distortion gets to unacceptable levels beyond the edges of the zones
- False northing for each zone in northern hemisphere is 0 and 10,000,000 for southern hemisphere.
- Egypt is covered by zones 35 (from 24E to 30 E) and 36 (from 30 E to 36 E).

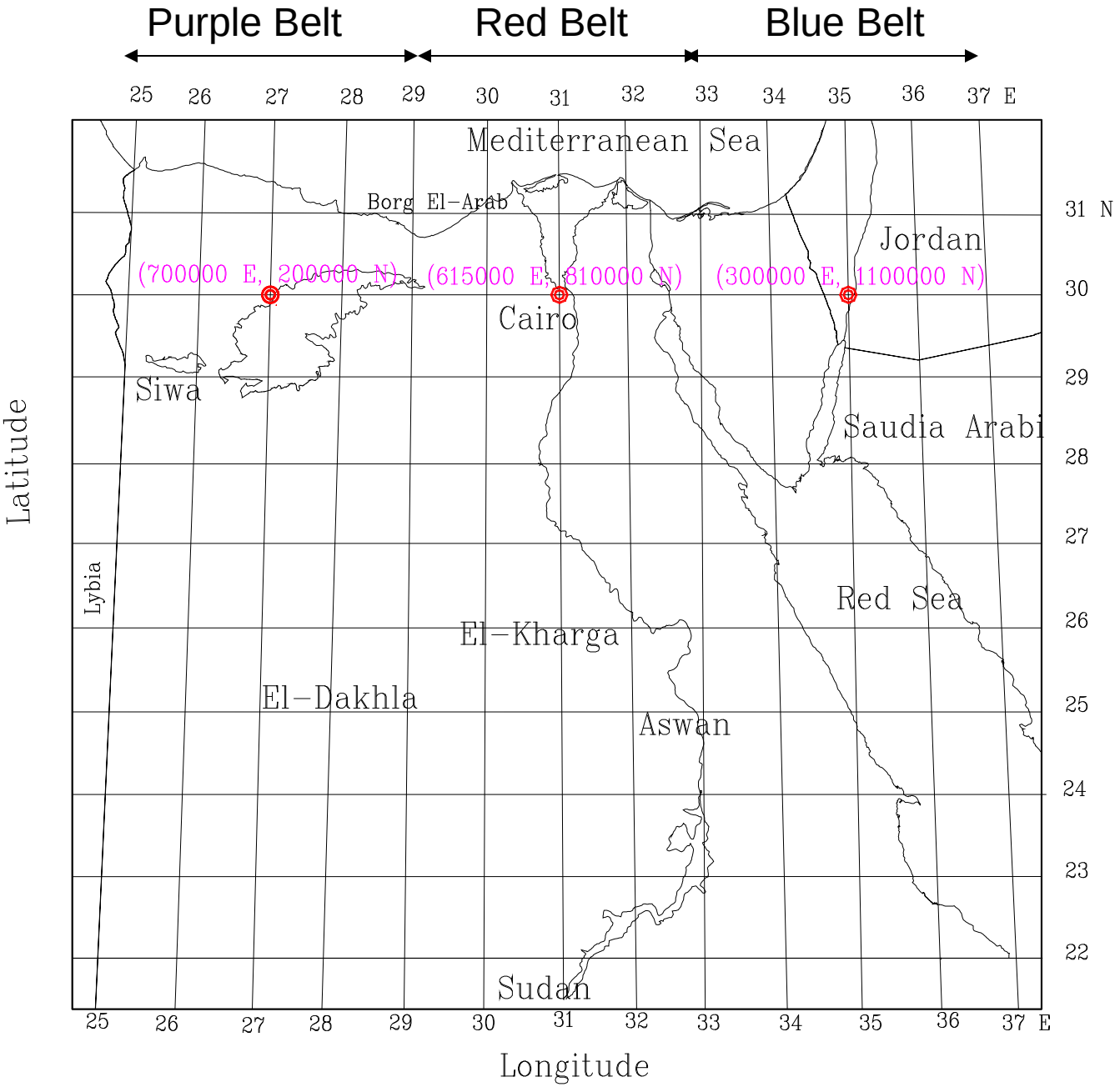
UTM zones


UTM Zone Numbers
0 1 0 2 0 3 0 4 0 5 0 6 0 7 0 8 0 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
84
72
64
56
48
40
32
24
16
8
0
-8
-16
-24
-32
-40
-48
-56
-64
-72
-80
X W V U T S R Q P N M L K J H G F E D C
UTM Zone Designators
-180 -168 -156 -144 -132 -120 -108 -96 -84 -72 -60 -48 -36 -24 -12 0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180
Universal Transverse Mercator (UTM) System
Peter H. Dana 9/7/94

Coordinate Systems for Egypt

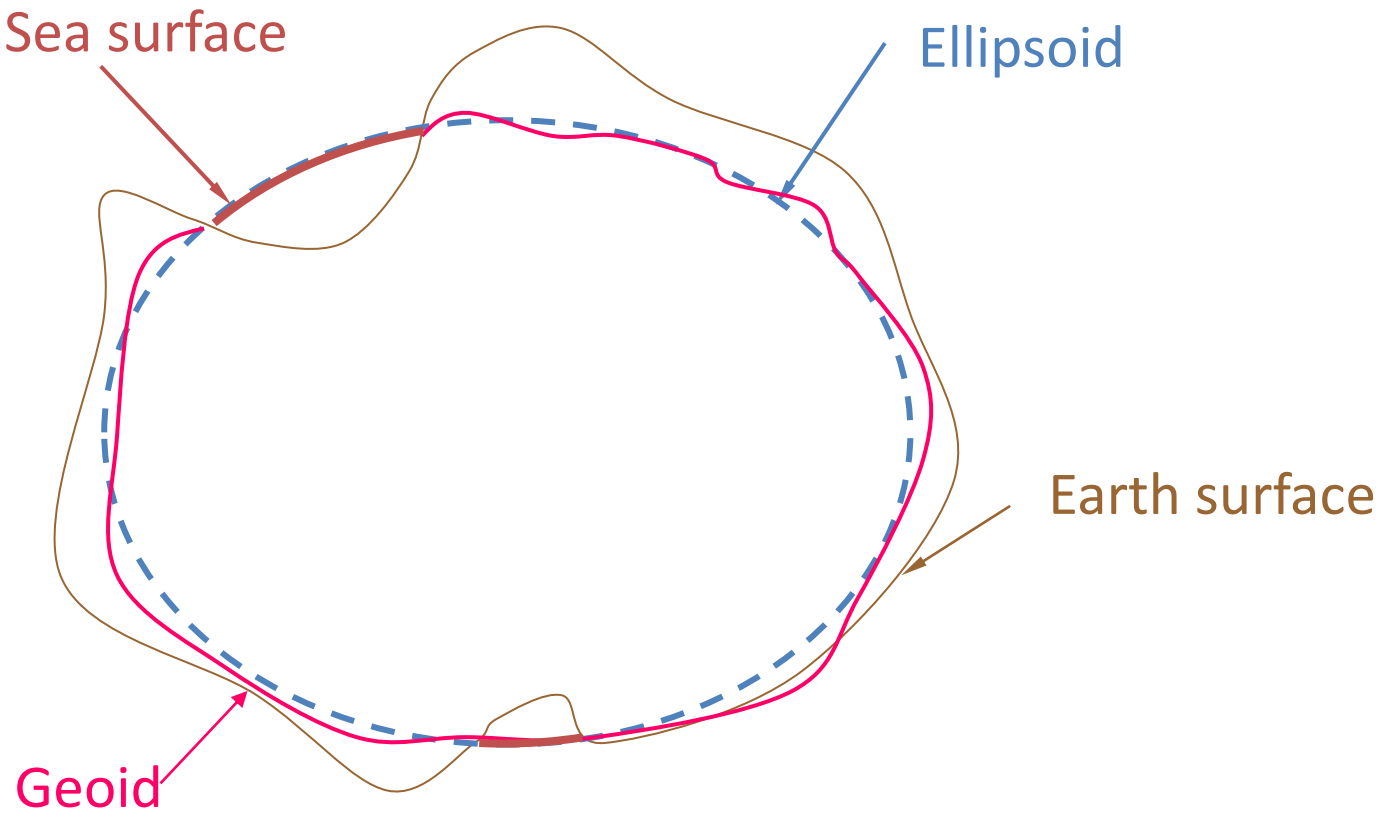
- The national geographic coordinates for Egypt has been defined with respect to ellipsoid Helmert 1906.
- Ellipsoid Helmert1906 as datum for geographic coordinates in Egypt is non-geocentric datum which deviates from center of earth by distance around 160m.
- The use of GPS in national positioning requires the transformation from GPS coordinates defined w.r.t WGS84 to national coordinates defined w.r.t. Helmert 1906.

Egyptian Transverse Mercator ETM



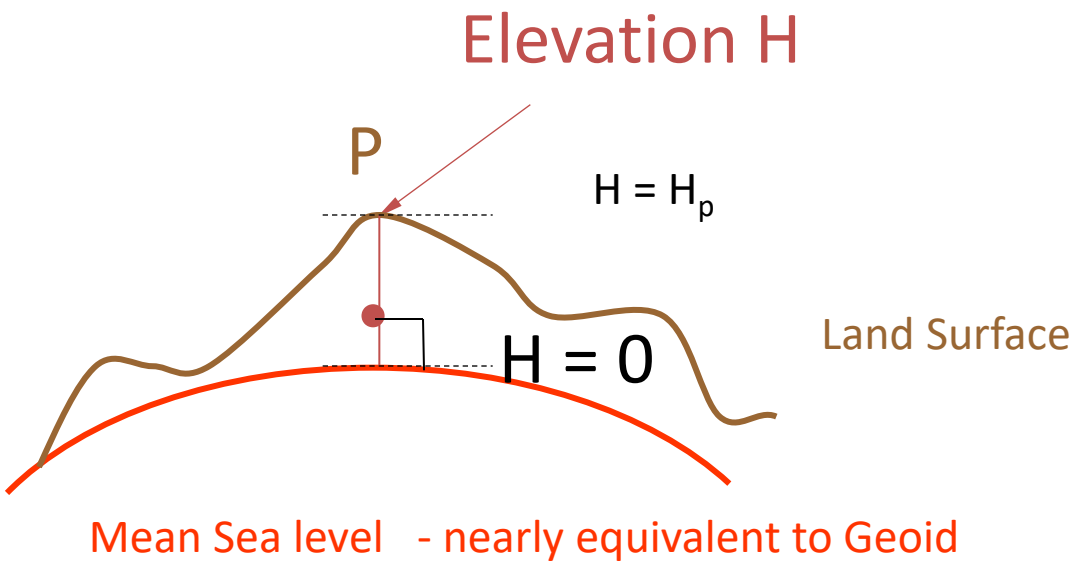
Representations of the Earth

Mean Sea Level is a surface of equipotential called the Geoid
Geoid is vertical datum



- Height defined by GPS is known by ellipsoidal height (height above ellipsoid surface.
- Height above geoid is known by orthometric height (level).
- Difference between ellipsoidal height and orthometric height is geoid separation or (geoid undulation).

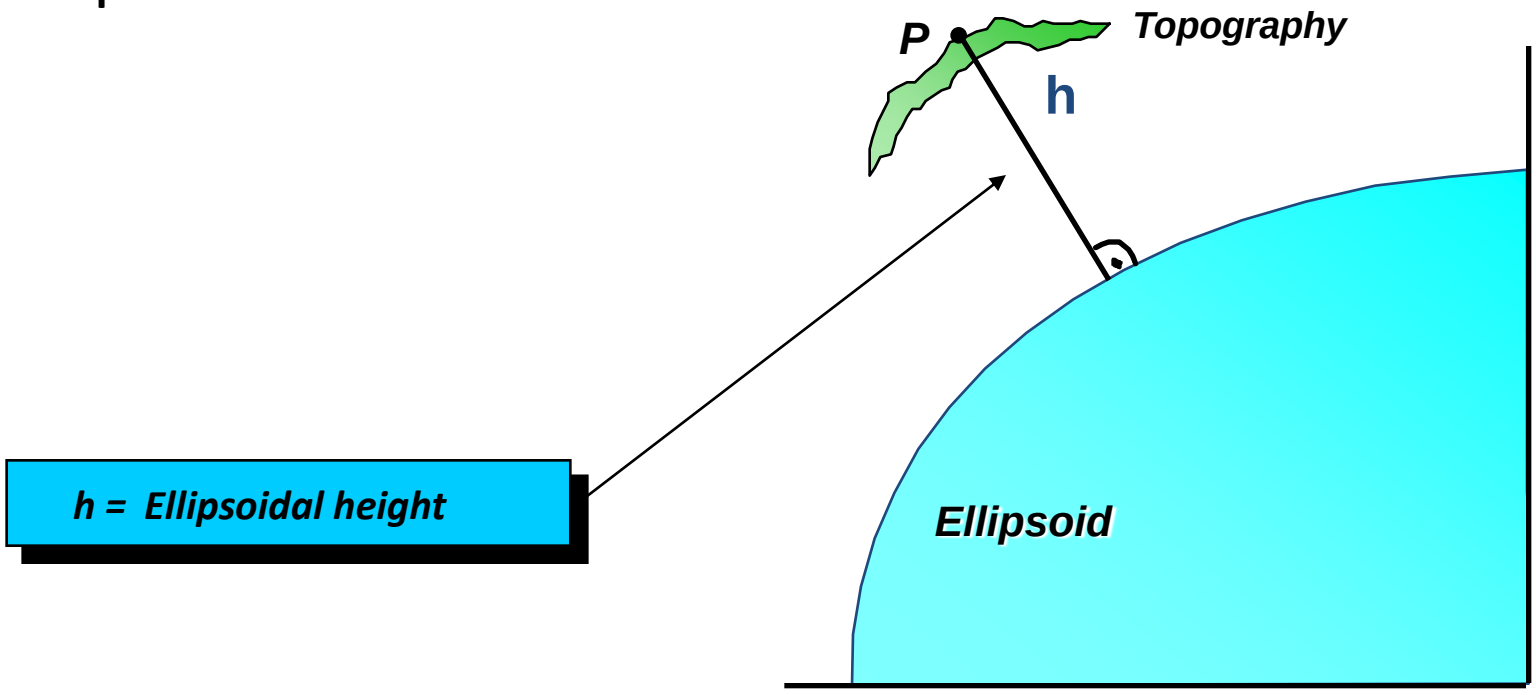
Definition of Elevation (Level)
Orthometric height H



Elevation is measured from the Geoid

Heighting

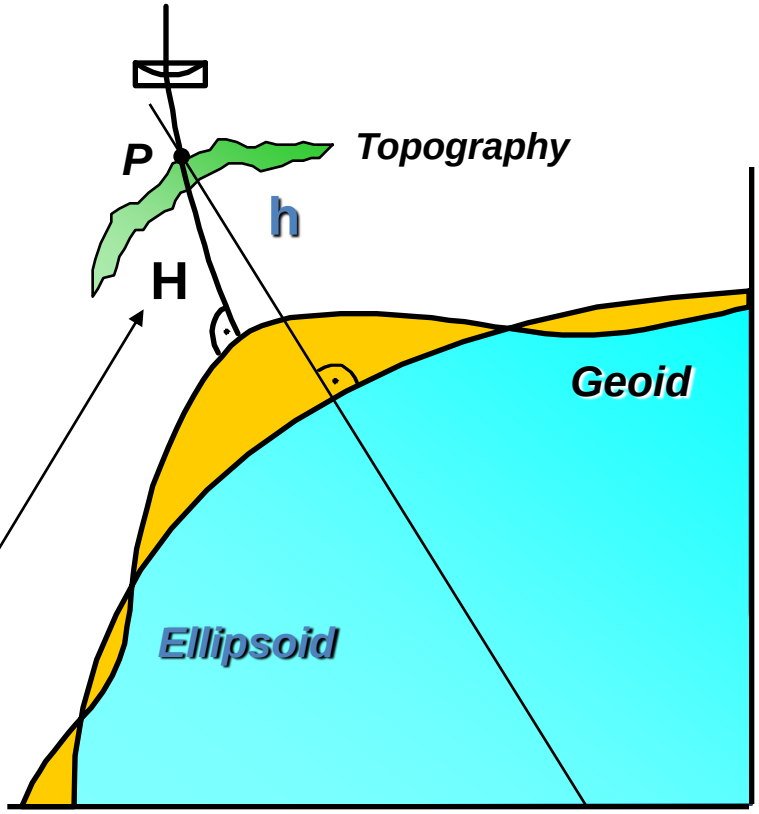
- **Heights determined using GPS are referenced to the WGS 84 Ellipsoid**
  - **Ellipsoid Heights are heights above the ellipsoid**



Heighting

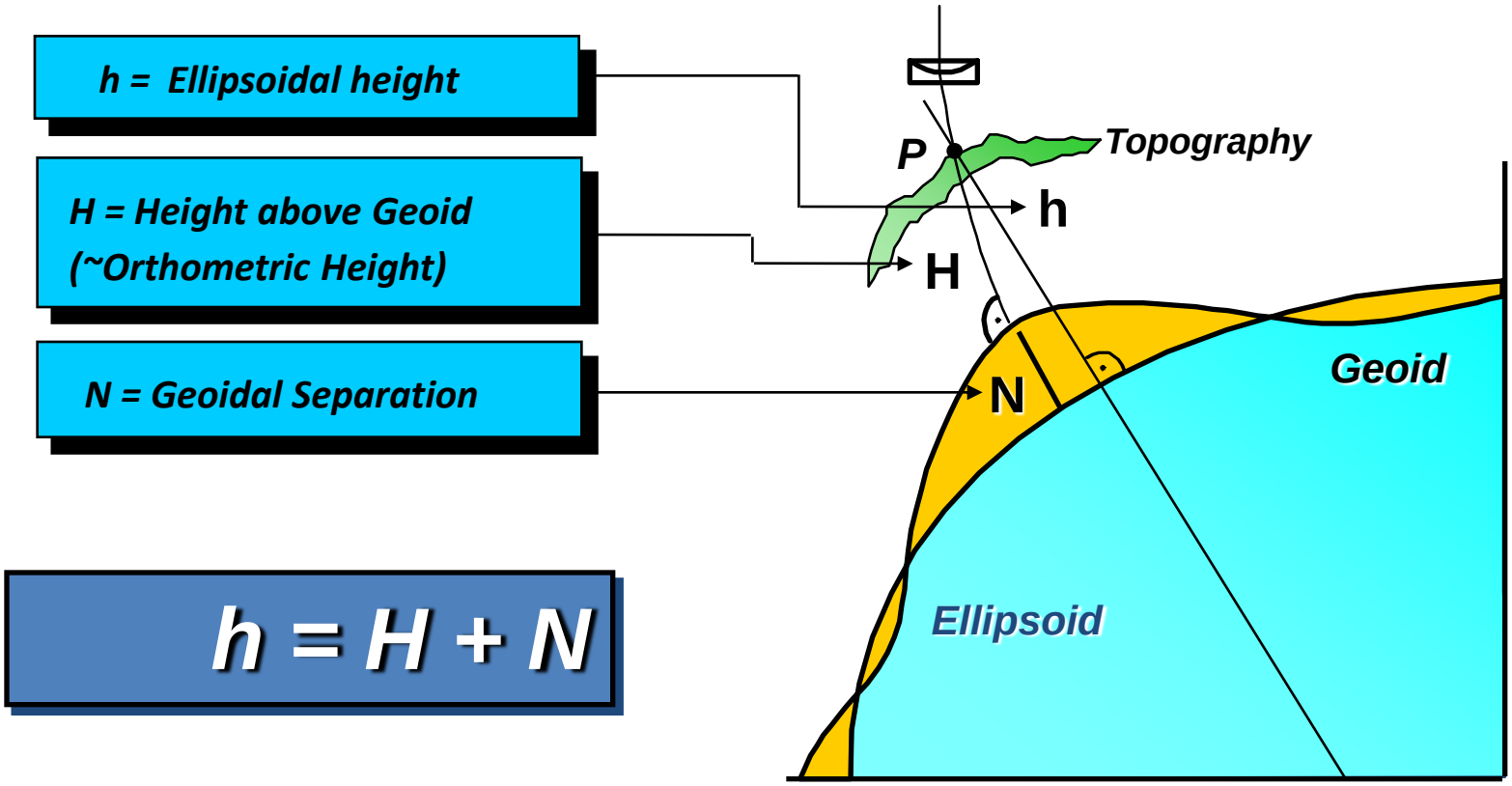
- The Geoid is that equipotential surface that best equates to Mean Sea Level
- The geoid undulates due to the effects of
  - Topography, geology etc.
- Orthometric heights are referenced to a Datum which is typically M.S.L
- M.S.L approximates the Geoid

H = Height above Geoid (~Orthometric Height)

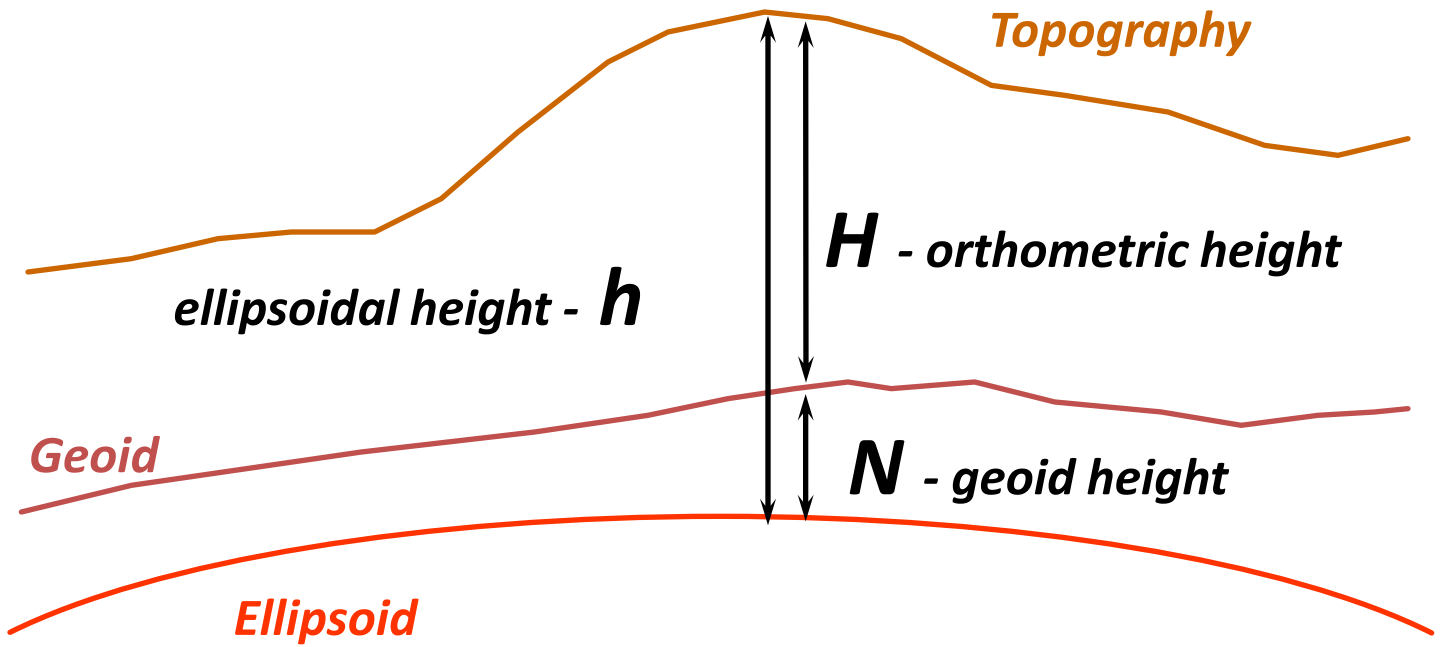


Heighting

- **The geoidal undulation may be positive or negative.**



Heighting


Topography
H - orthometric height
ellipsoidal height - h
Geoid
N - geoid height
Ellipsoid