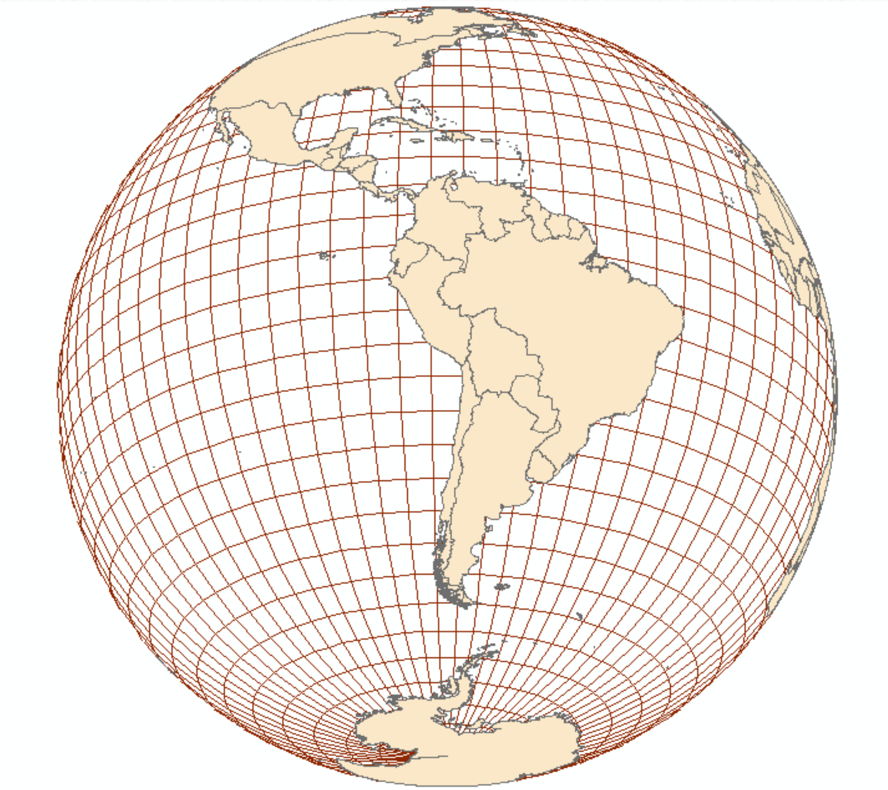
Map Projection



Md. Abdul Malek

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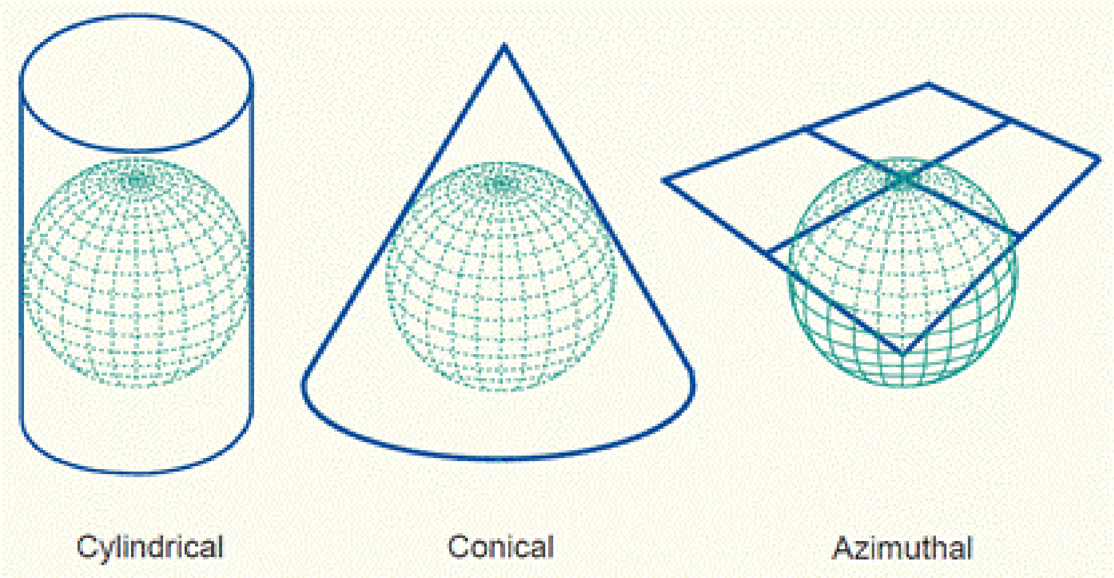
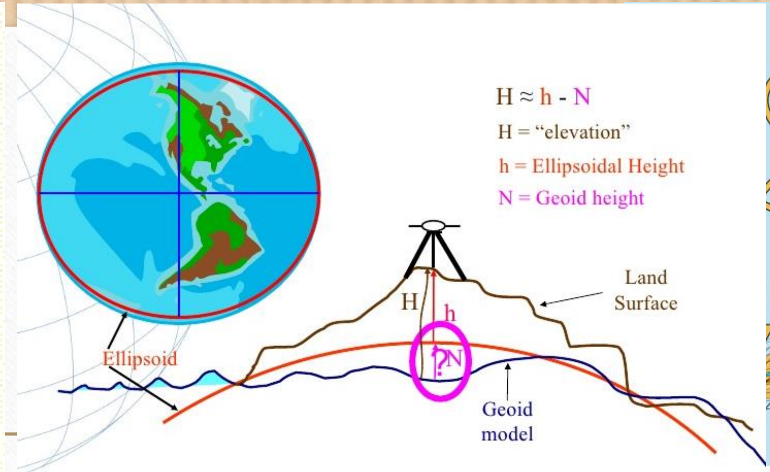
Terms

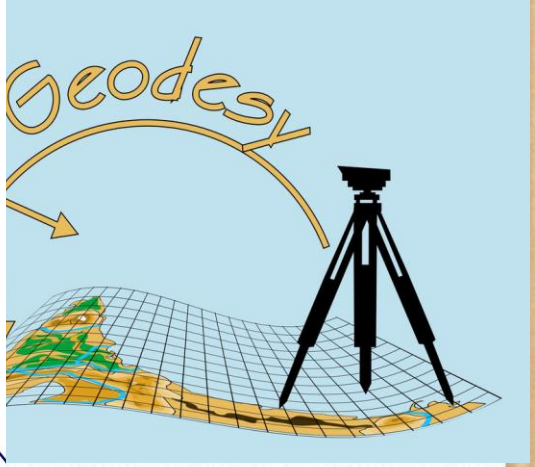
Geodesy:- The science of determining the size and shape of the earth and the precise location of points on its surface.

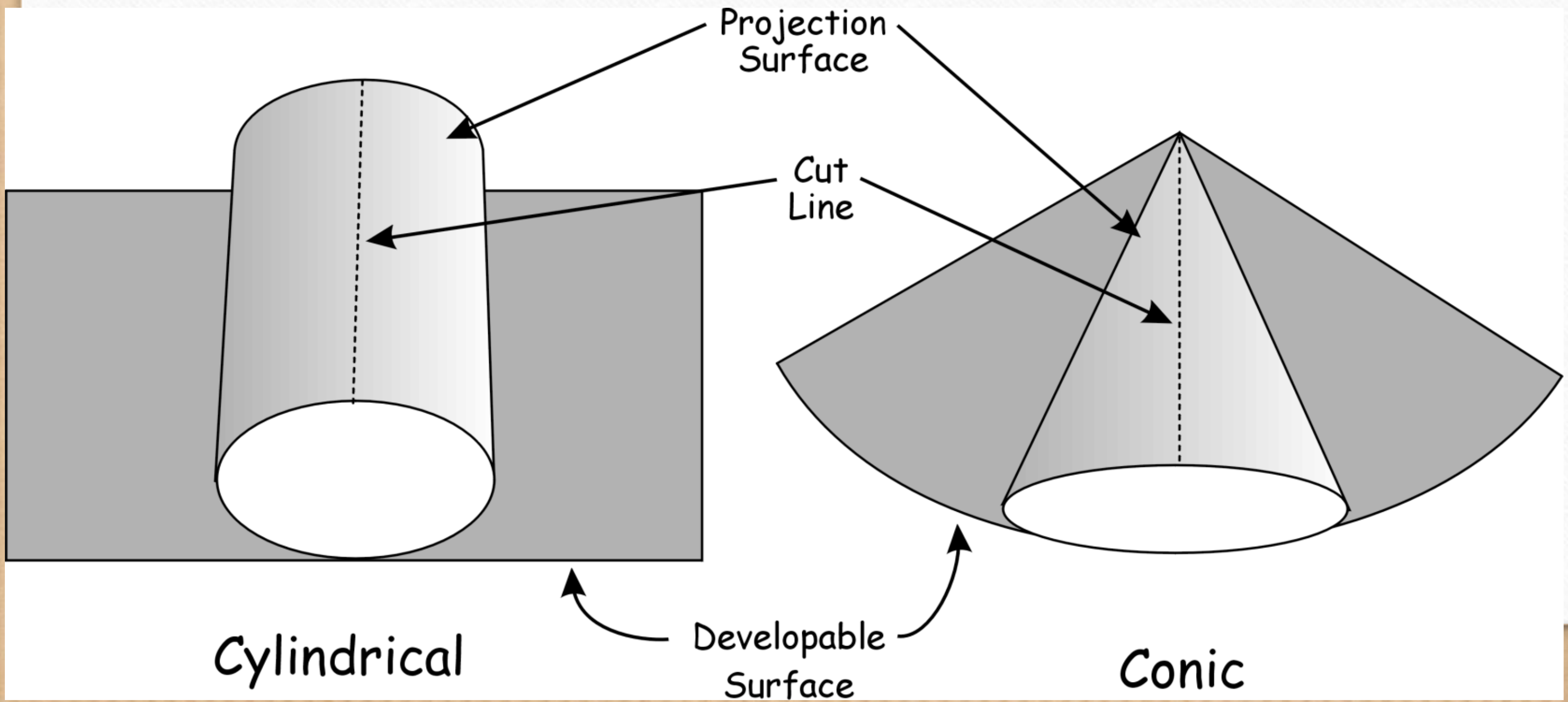
Map Projection:- The transformation of a curved earth to a flat map.

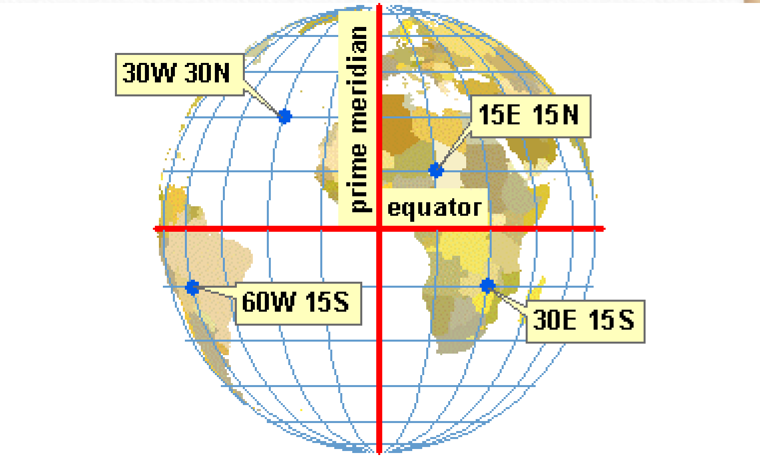
Coordinate systems: – Any set of numbers, usually in sets of two or three, used to determine location relative to other locations in two or three dimensions

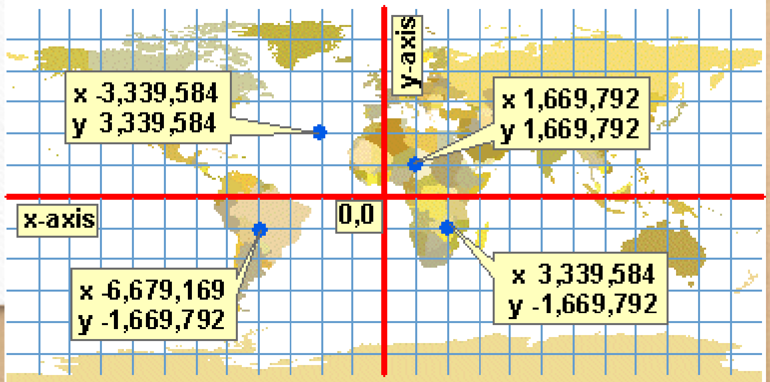

Cylindrical
Conical
Azimuthal


H ≈ h - N
H = "elevation"
h = Ellipsoidal Height
N = Geoid height
Land
Surface
H
h
N
Ellipsoid
Geoid
model


Geodesy


Projection
Surface
Cut
Line
Cylindrical
Developable
Surface
Conic


30W 30N
prime meridian
15E 15N
equator
60W 15S
30E 15S


y-axis
x -3,339,584
y 3,339,584
x 1,669,792
y 1,669,792
x-axis
0,0
x -6,679,169
y -1,669,792
x 3,339,584
y -1,669,792

Map Projection

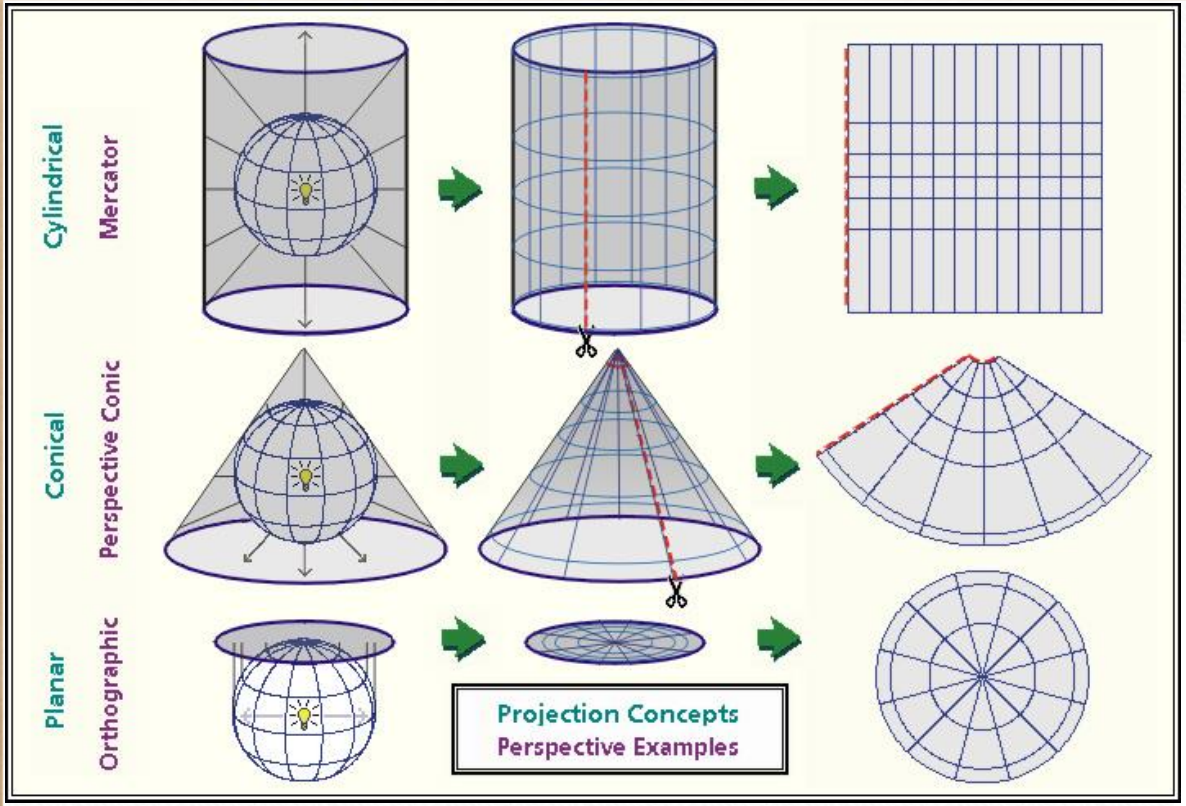
A **map projection** is a systematic transformation of the *latitudes* and *longitudes* of locations from the surface of a sphere or an ellipsoid into locations on a plane.

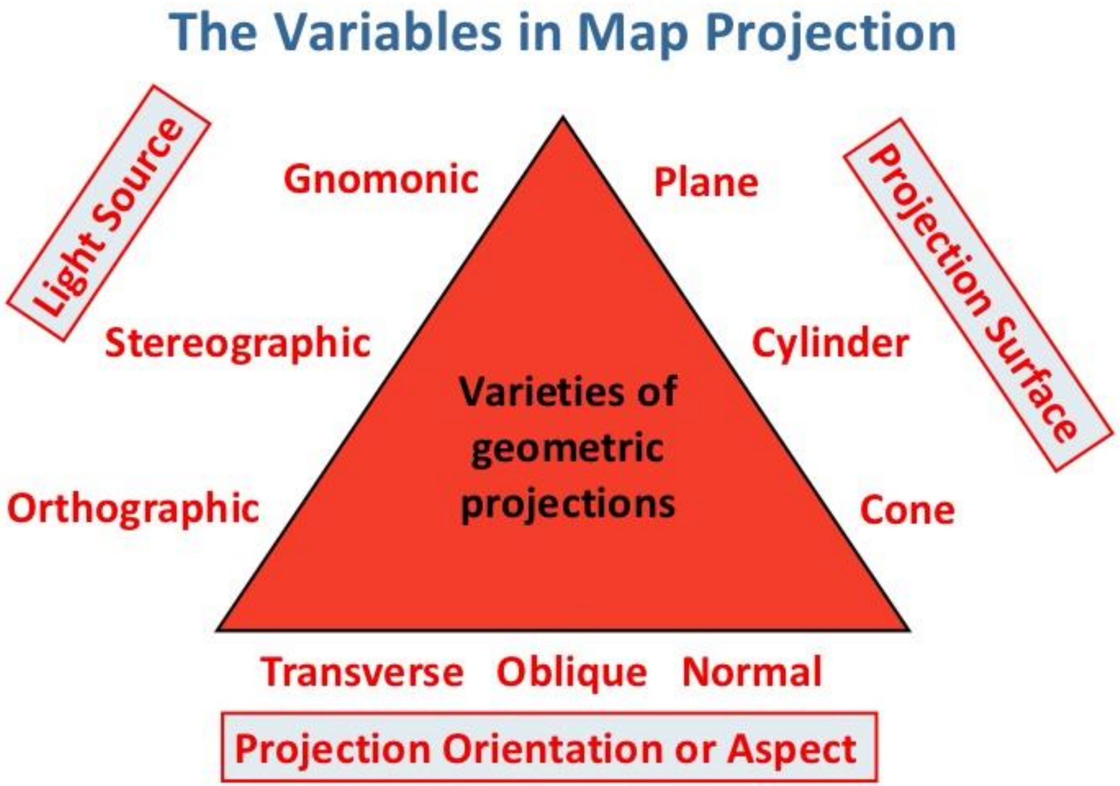
Maps cannot be created without map projections. All map projections necessarily distort the surface in some fashion.

Depending on the purpose of the map, some distortions are acceptable and others are not; therefore, different map projections exist in order to preserve some properties of the sphere-like body at the expense of other properties.

There is no limit to the number of possible map projections.

Even more generally, projections are a subject of several pure mathematical fields, including differential geometry, projective geometry, and manifolds. However, "map projection" refers specifically to a cartographic projection.


Cylindrical
Mercator
Conical
Perspective Conic
Planar
Orthographic
Projection Concepts
Perspective Examples


The Variables in Map Projection
Light Source
Gnomonic
Stereographic
Orthographic
Projection Surface
Plane
Cylinder
Cone
Varieties of geometric projections
Transverse
Oblique
Normal
Projection Orientation or Aspect

Scale

Maps are a graphical representation of the world or a section of the world. As a representation of the world, maps are compressed versions of the real world meaning that a large piece of land is recreated onto a smaller piece of paper or digital file.

The relationship between the real world size of a geographic feature and its representative feature on a map is known as scale.

Scale is often represented as a ratio between the real world size and the size in units on the map.

There are three main ways that scale is indicated on a map: **graphic** (or bar), **verbal**, and **representative fraction** (RF).

Types of Coordinate Systems

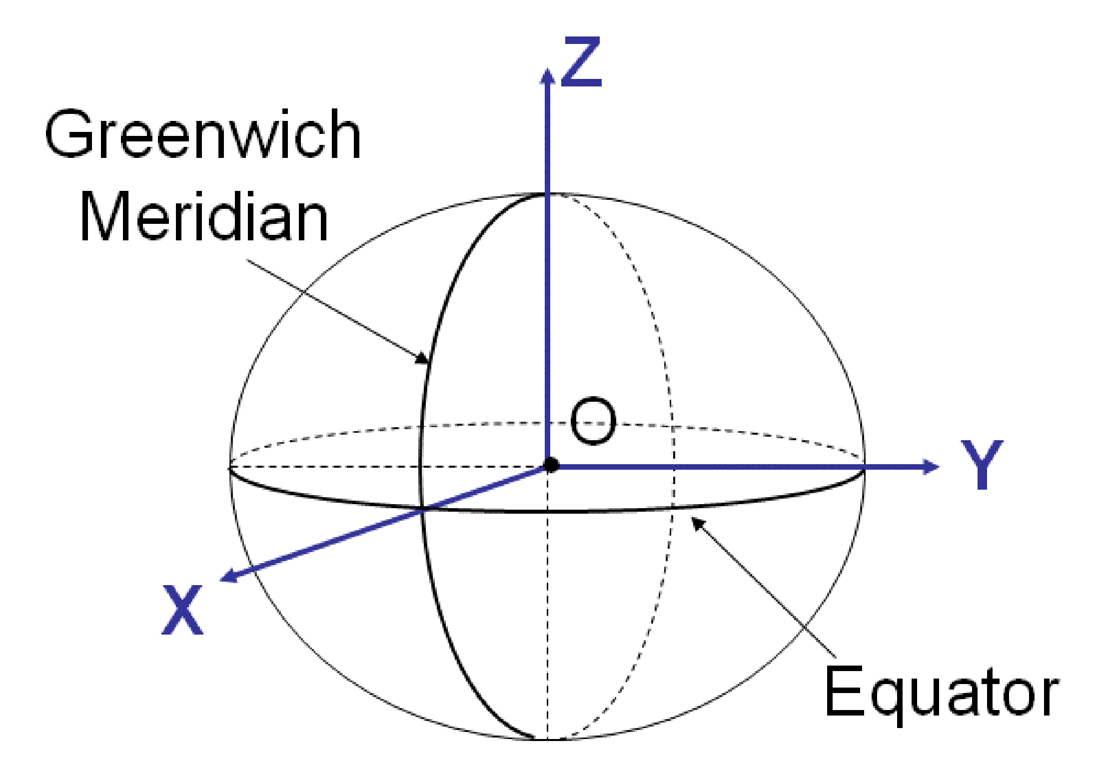
(1) Global Cartesian coordinates (x,y,z): A system for the whole earth

(2) Geographic coordinates (ϕ, λ, z)

(3) Projected coordinates (x, y, z) on a local area of the earth's surface

The z-coordinate in (1) and (3) is defined geometrically; in (2) the z-coordinate is defined gravitationally

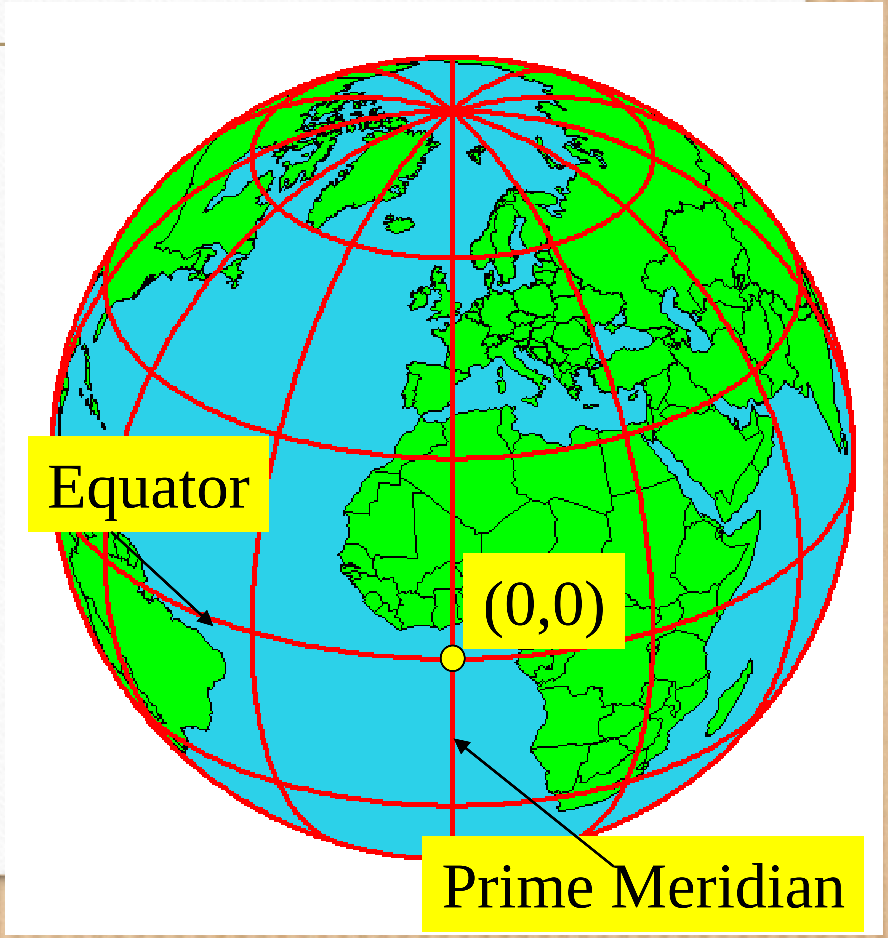
Global Cartesian Coordinates (x, y, z)



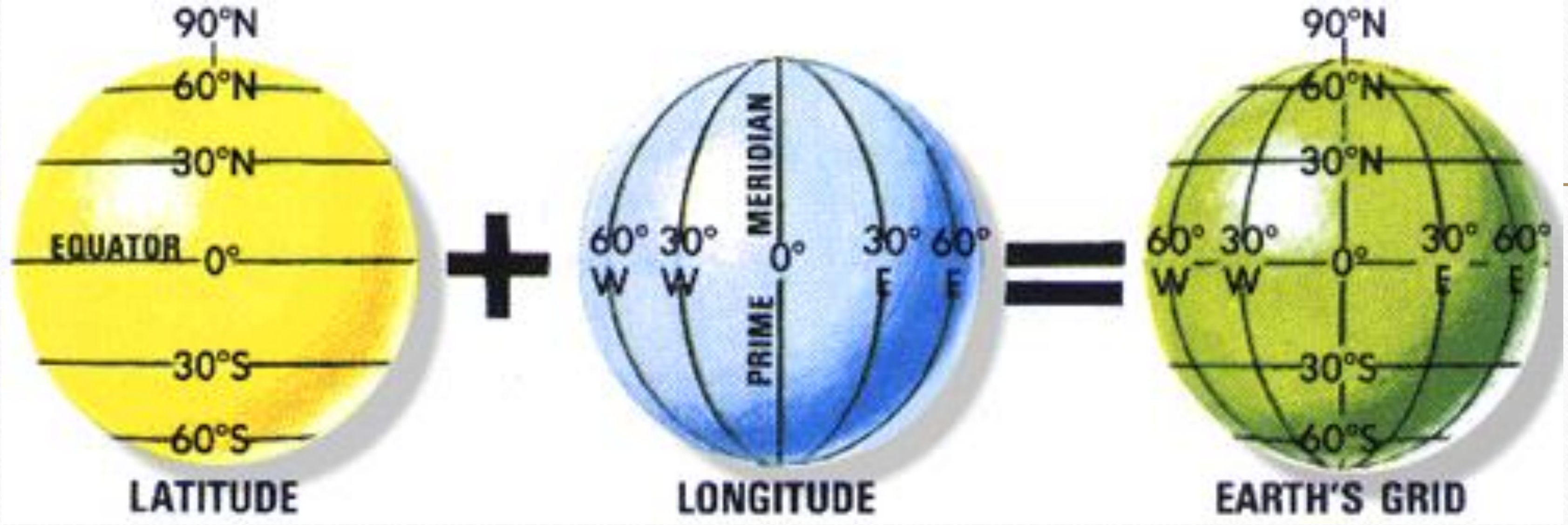
Extremely cumbersome and difficult to relate to other locations when translated to two dimensions.

Geographic Coordinates (Latitude and Longitude) (ϕ, λ, z)

- ✓Latitude (ϕ) and Longitude (λ) defined using an ellipsoid, an ellipse rotated about an axis
- ✓Elevation (z) defined using geoid, a surface of constant gravitational potential.
- ✓Earth datums define standard baseline values of the ellipsoid and geoid.
- ✓Usually used in general purpose atlases and maps and textbooks.



Latitude and Longitude

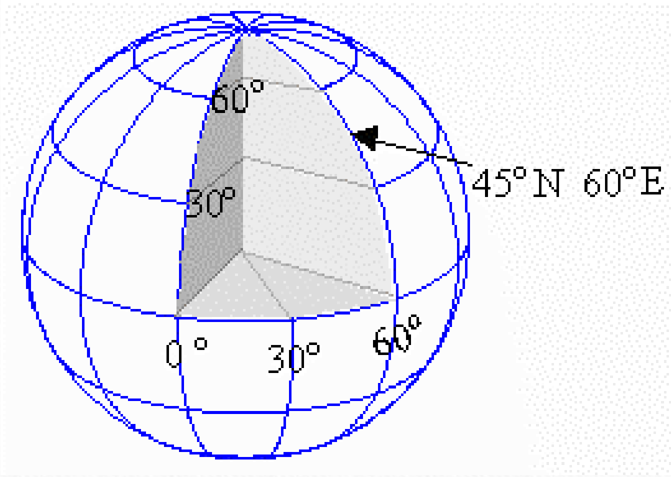


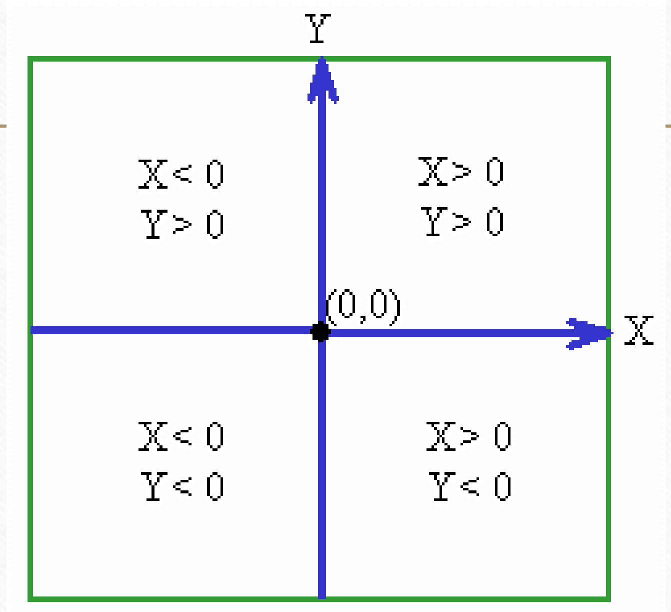
Lines of latitude are called "parallels"

Lines of longitude are called "meridians"

The Prime Meridian passes through Greenwich, England

Projected Coordinates





(ϕ, λ) ⟷ (x, y)

Map Projection

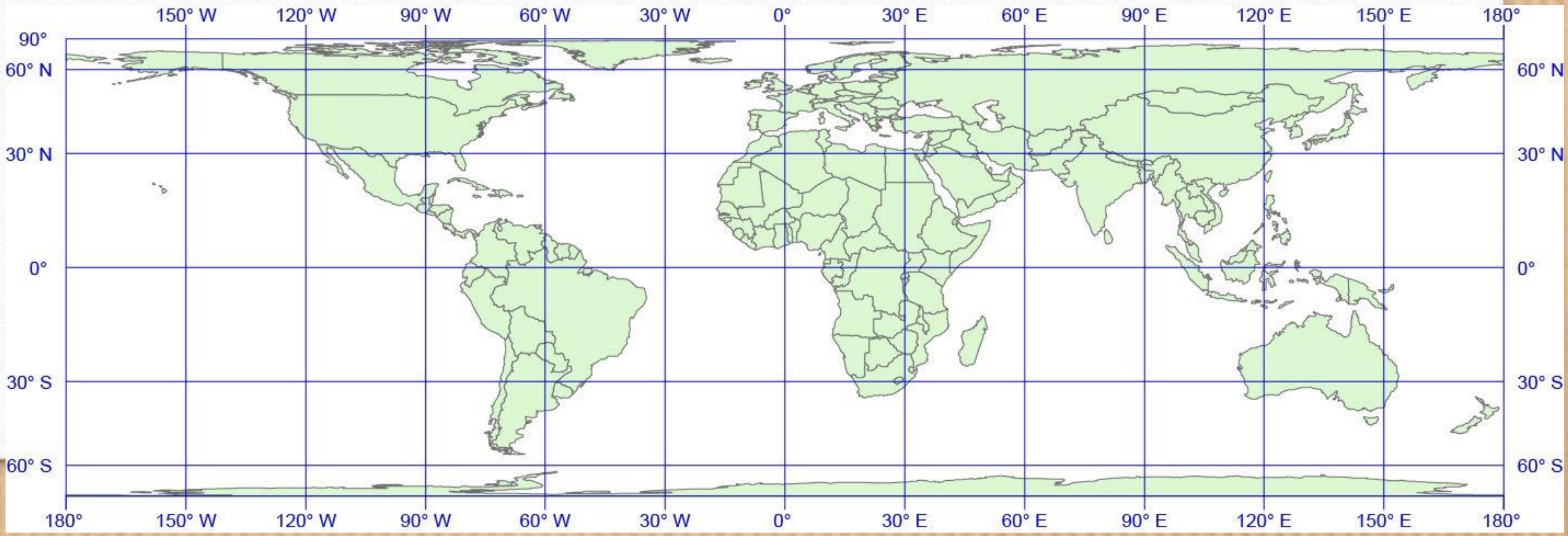
Classifications of Map Projections

- ✓ **Conformal** – local shapes are preserved
- ✓ **Equal-Area** – areas are preserved
- ✓ **Equidistant** – distance from a single location to all other locations are preserved
- ✓ **Azimuthal** – directions from a single location to all other locations are preserved

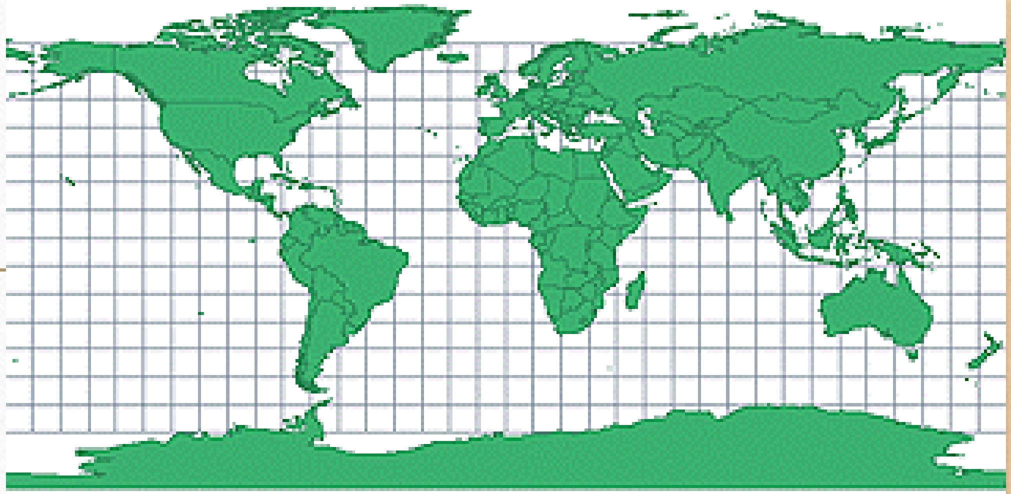
Conformal Projection

- ✓ Preserve shape (only for small areas)
- ✓ Preserve Angles
- ✓ Used for large scale mapping
- ✓ Distortion increases outwards from the central meridian and standard parallel

Equal-Area



Equidistant Projection



- ✓ Constant scale
- ✓ Maintains accurate distances from the center of the projection or along given lines
- ✓ Plate carree equidistant cylindrical, equirectangular azimuthal equidistant projection
- ✓ Radio and seismic mapping, navigation

Azimuthal Projection

Maintains accurate directions (and therefore angular relationships) from a given central point. Used for aeronautical charts and other maps where directional relationships are important

Azimuthal Projection

Another Classification Systems

A fundamental projection classification is based on the type of projection surface onto which the globe is conceptually projected. The projections are described in terms of placing a gigantic surface in contact with the earth, followed by an implied scaling operation. These surfaces are

- ✓ Cylindrical (e.g. Mercator),
- ✓ Conic (e.g. Albers or Robinson), and
- ✓ Plane (e.g. stereographic).

Many mathematical projections, however, do not neatly fit into any of these three conceptual projection methods. Hence other peer categories have been described in the literature, such as

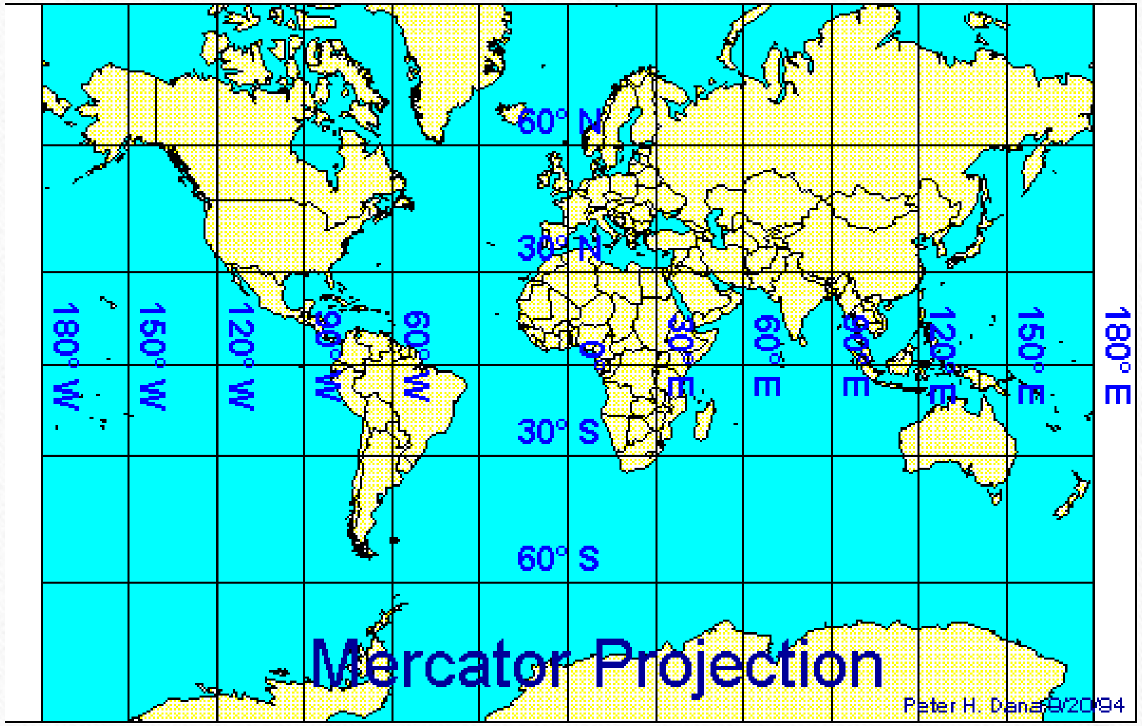
pseudoconic, **pseudocylindrical**, **pseudoazimuthal**, **retroazimuthal**, and **polyconic**.

Mercator Projection

✓ Most Accurate in the tropics from Cancer to Capricorn

✓ Most Distortion at the North and South Poles.

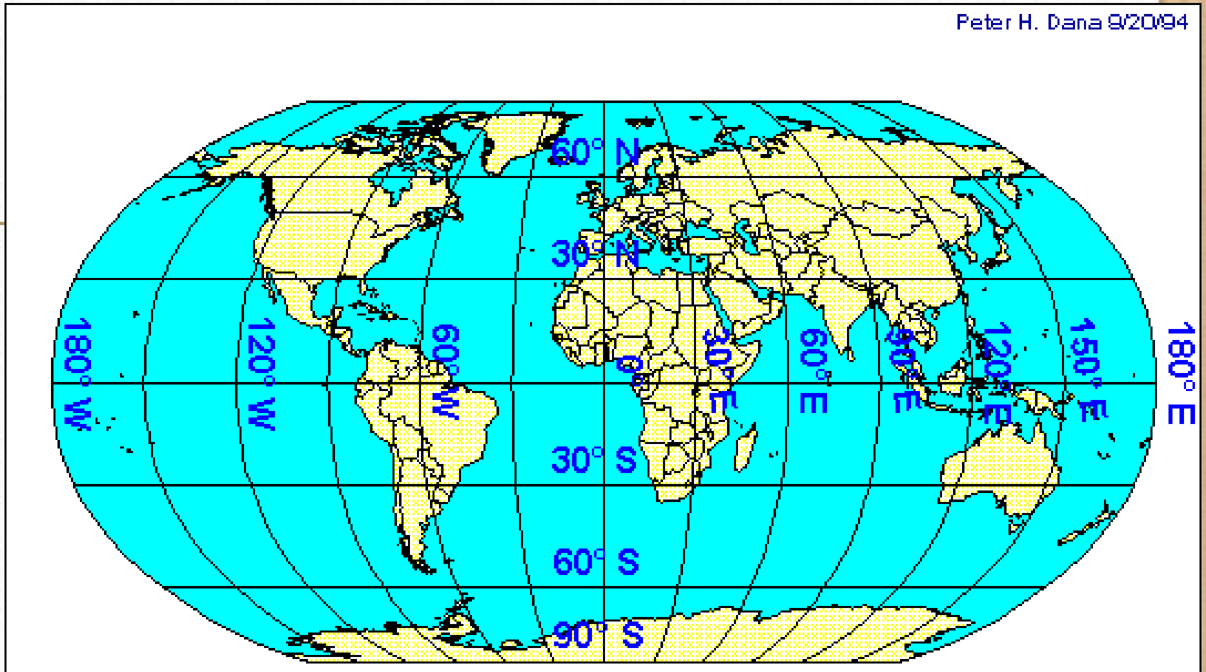
- **Used for:**
  - Locating Latitude and Longitude
  - Sea captains use it for navigation at sea
- **Characteristics:**
  - All lines are at 90 degree angles
  - Simplest to read
  - Accurate direction
  - Distorted size, distance, shape



Robinson Projection

✓ Same characteristic as the Mercator **except**:-

- Lines of longitude are curved
- Shapes at the poles are flat and not as distorted
- Used mostly in classrooms-one of the most accurate maps.

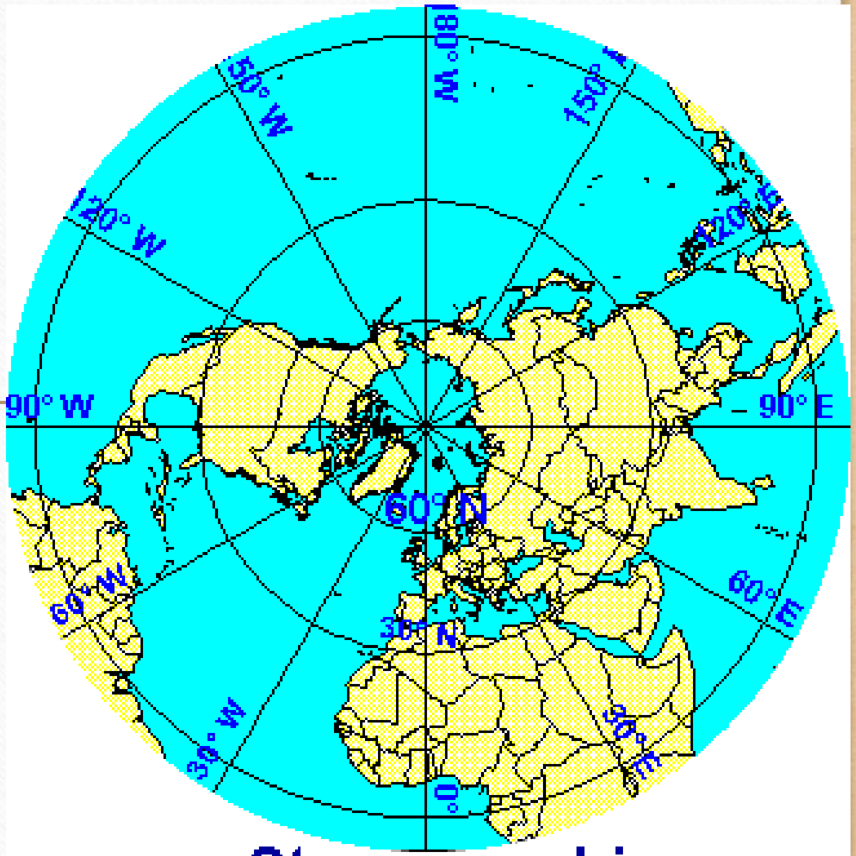


Robinson Projection

Polar Projection

✓ Most Accurate at the poles

✓ Most Distortion around the outer edges.



Stereographic
North Polar Aspect

➢ **Used for:**

- Navigation of air planes

➢ **Characteristics:**

- Distances and direction are accurate from the center along the longitude lines.
- Size and shape are accurate at the center of the map

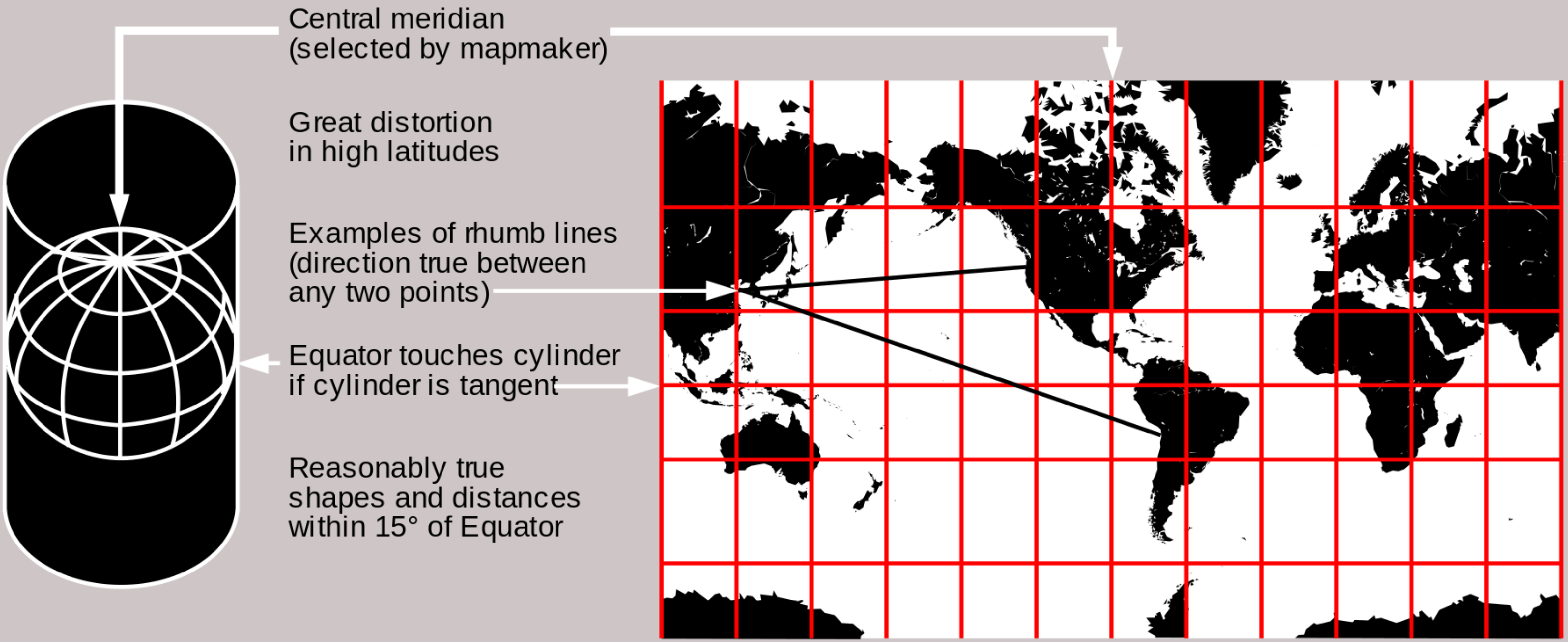
Cylindrical Projection

A "normal cylindrical projection" is any projection in which meridians are mapped to equally spaced vertical lines and circles of latitude (parallels) are mapped to horizontal lines.

The mapping of meridians to vertical lines can be visualized by imagining a cylinder whose axis coincides with the Earth's axis of rotation. This cylinder is wrapped around the Earth, projected onto, and then unrolled.

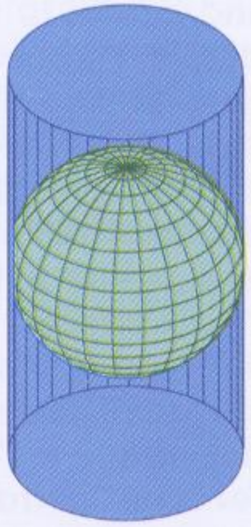
The amount of stretch is the same at any chosen latitude on all cylindrical projections, and is given by the secant of the latitude as a multiple of the equator's scale.

The various cylindrical projections are distinguished from each other solely by their north-south stretching (where latitude is given by φ):

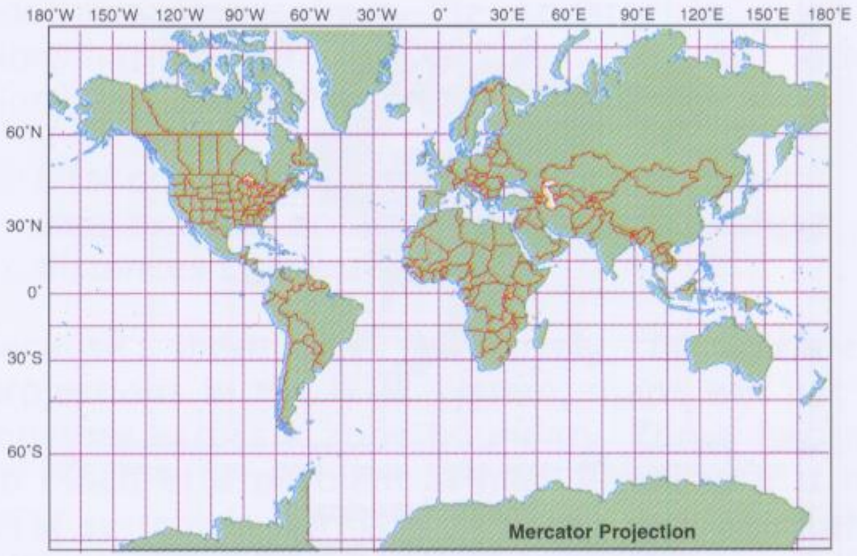


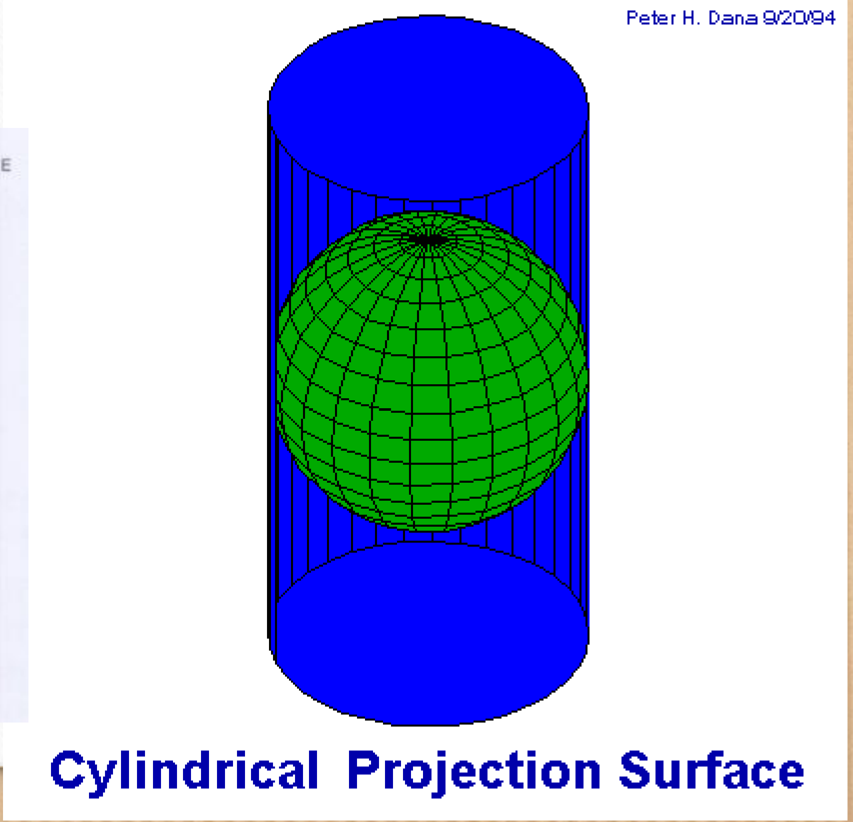
Central meridian
(selected by mapmaker)
Great distortion
in high latitudes
Examples of rhumb lines
(direction true between
any two points)
Equator touches cylinder
if cylinder is tangent
Reasonably true
shapes and distances
within 15° of Equator

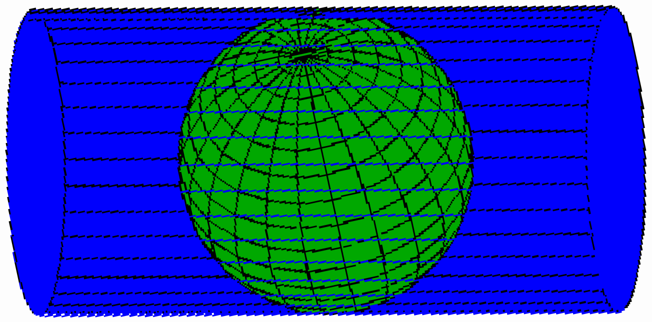
- ✓ Projecting spherical Earth surface onto a cylinder
- ✓ Cylinder is assumed to surround the transparent reference globe
- ✓ Cylinder touches the reference globe at equator



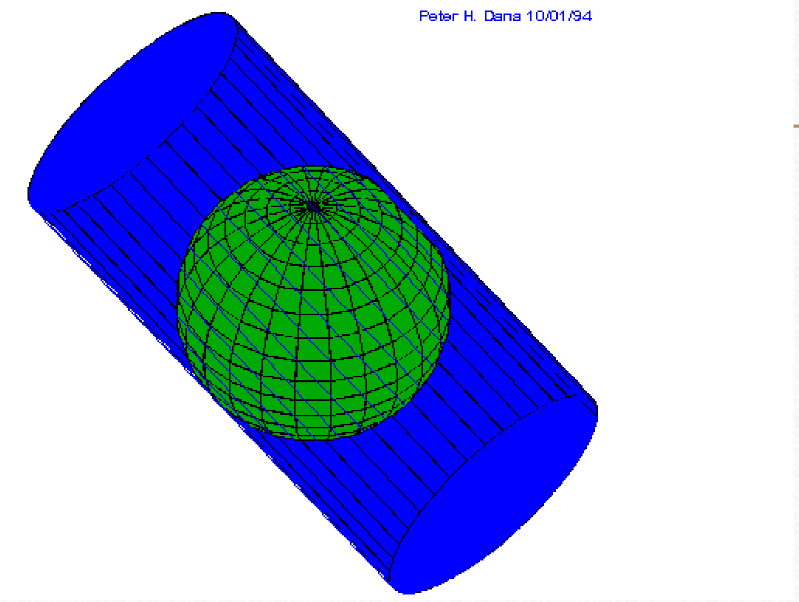
Cylindrical Projection Surface



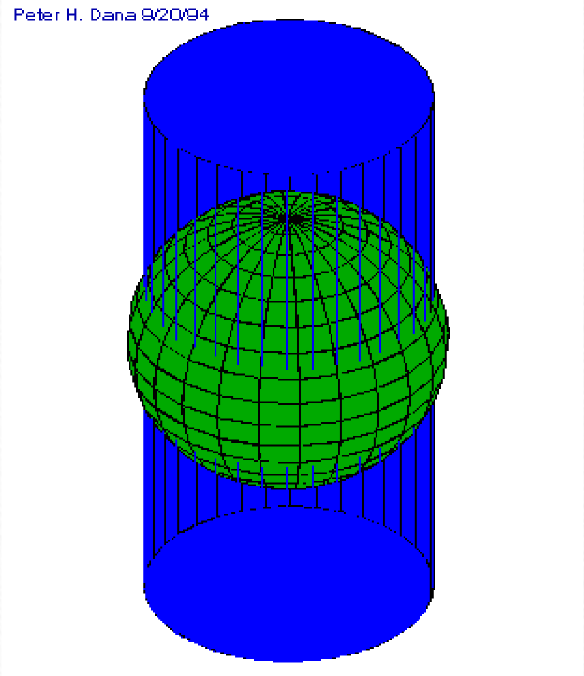




Transverse Cylindrical



Oblique Cylindrical



Secant Cylindrical

- ✓ North-south stretching equals east-west stretching (secφ): The east-west scale matches the north-south scale: conformal cylindrical or Mercator.
- ✓ North-south stretching grows with latitude faster than east-west stretching (sec^2 φ): The cylindric perspective (or central cylindrical) projection.
- ✓ North-south stretching grows with latitude, but less quickly than the east-west stretching: such as the Miller cylindrical projection (sec 4/5φ).
- ✓ North-south distances neither stretched nor compressed (1): equirectangular projection or "plate carrée".
- ✓ North-south compression equals the cosine of the latitude (the reciprocal of east-west stretching): equal-area cylindrical. This projection has many named specializations differing only in the scaling constant, such as the Gall–Peters or Gall orthographic (undistorted at the 45° parallels), Behrmann (undistorted at the 30° parallels), and Lambert cylindrical equal-area (undistorted at the equator).

- In the first case (Mercator), the east-west scale always equals the north-south scale.
- In the second case (central cylindrical), the north-south scale exceeds the east-west scale everywhere away from the equator.
- Each remaining case has a pair of secant lines—a pair of identical latitudes of opposite sign (or else the equator) at which the east-west scale matches the north-south-scale.
- Normal cylindrical projections map the whole Earth as a finite rectangle, except in the first two cases, where the rectangle stretches infinitely tall while retaining constant width.

Examples: Mercator, Transverse Mercator, Oblique Mercator etc.

Pseudocylindrical Projection

Pseudocylindrical projections represent the central meridian as a straight line segment. Other meridians are longer than the central meridian and bow outward, away from the central meridian. Pseudocylindrical projections map parallels as straight lines.

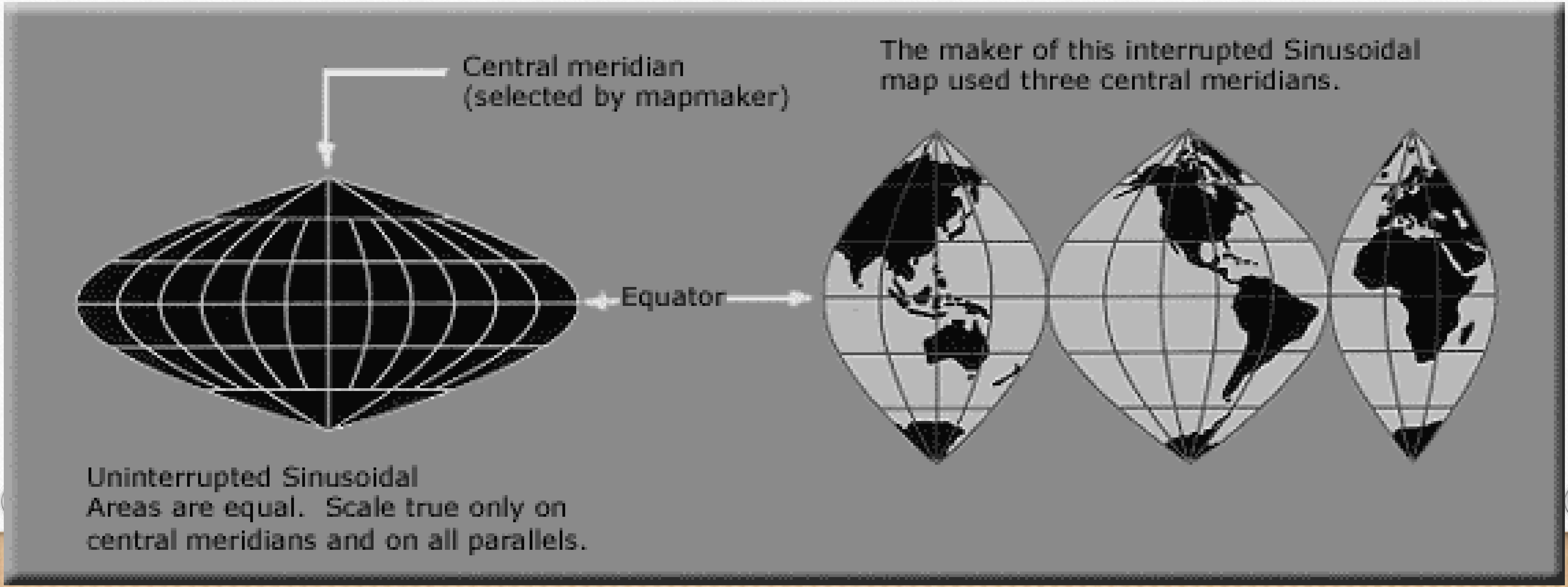
On a pseudocylindrical map, any point further from the equator than some other point has a higher latitude than the other point, preserving north-south relationships. This trait is useful when illustrating phenomena that depend on latitude, such as climate. Examples of pseudocylindrical projections include:

- Sinusoidal, which was the first pseudocylindrical projection developed. On the map, as in reality, the length of each parallel is proportional to the cosine of the latitude.
- Collignon projection, which in its most common forms represents each meridian as two straight line segments, one from each pole to the equator.


Tobler hyperelliptical


Mollweide


Eckert IV

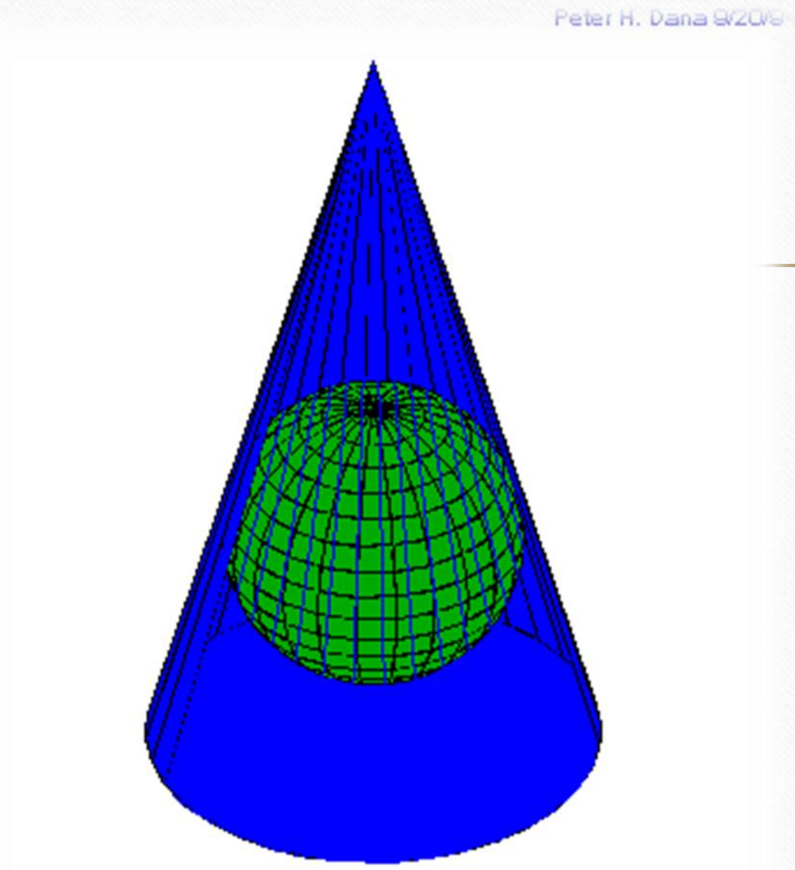

Central meridian
(selected by mapmaker)
The maker of this interrupted Sinusoidal
map used three central meridians.
Equator
Uninterrupted Sinusoidal
Areas are equal. Scale true only on
central meridians and on all parallels.

Conic Projection

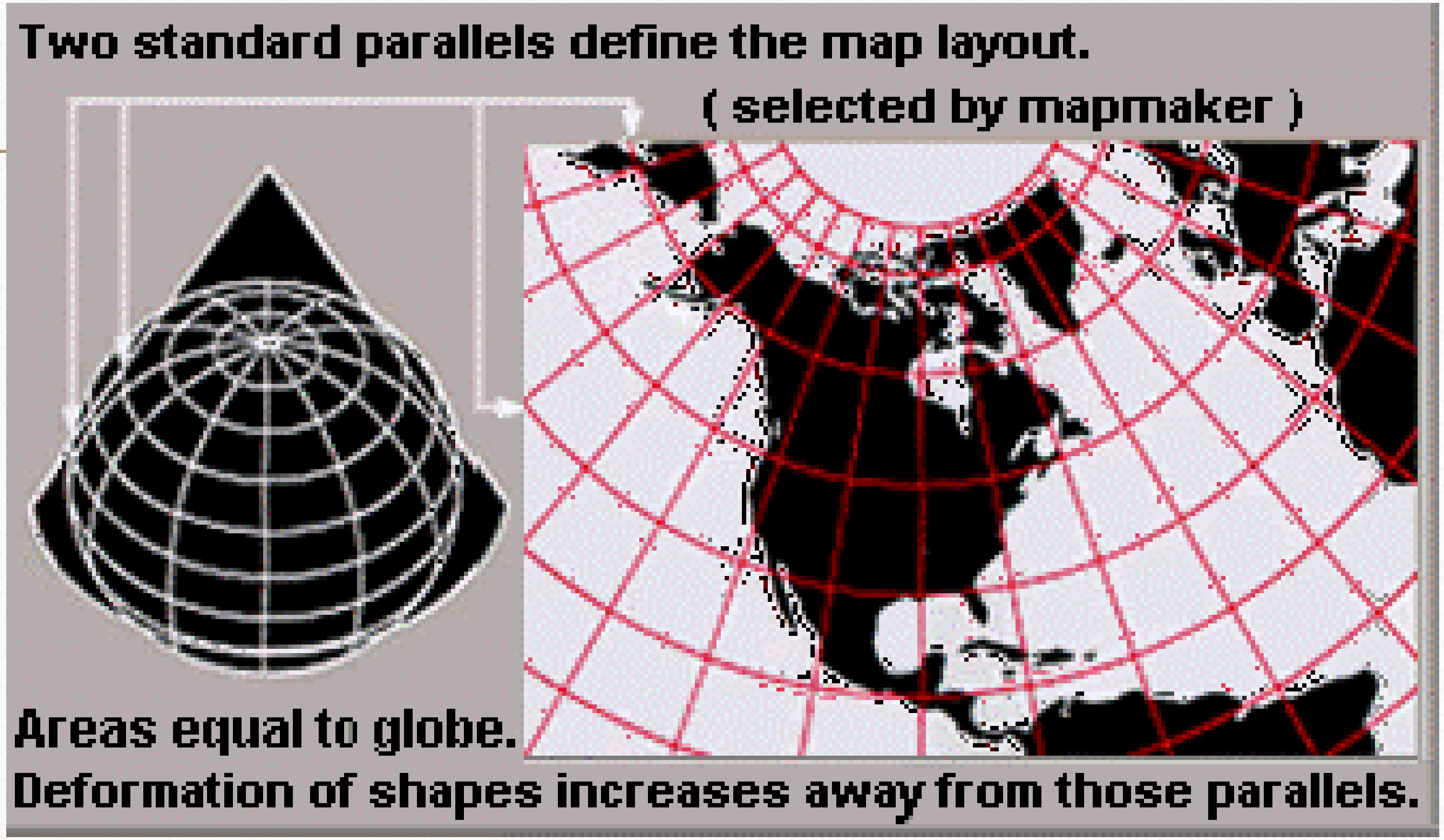
The term "conic projection" is used to refer to any projection in which meridians are mapped to equally spaced lines radiating out from the apex and circles of latitude (parallels) are mapped to circular arcs centered on the apex.

- A conic is placed over the reference globe in such a way that the apex of the cone is exactly over the polar axis
- The cone touches the globe at standard parallel
- Along this standard parallel the scale is correct with least distortion

The resulting conic map has low distortion in scale, shape, and area near those standard parallels.



Conical Projection Surface

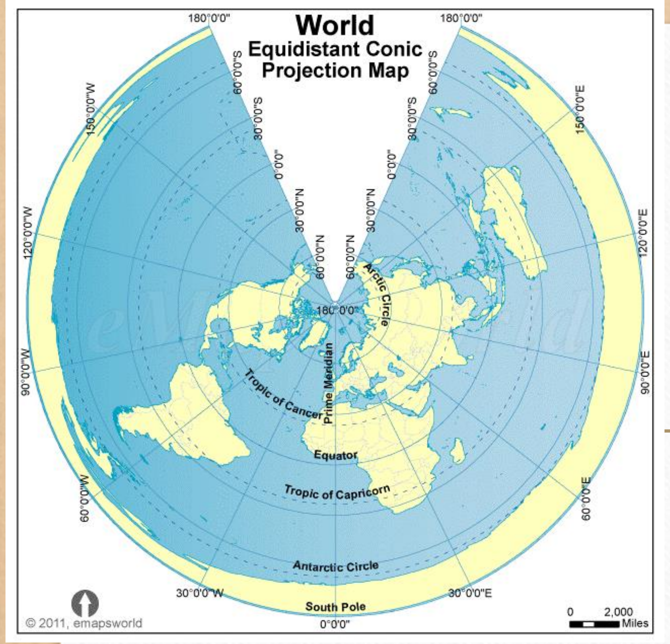


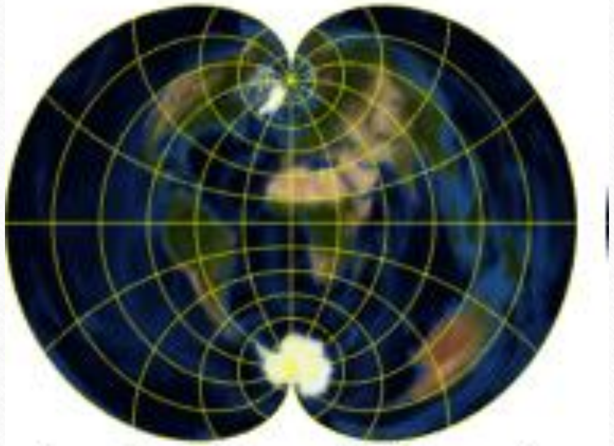
Conic projections that are commonly used are:

- ✓ Equidistant conic, which keeps parallels evenly spaced along the meridians to preserve a constant distance scale along each meridian.
- ✓ Albers conic, which adjusts the north-south distance between non-standard parallels to compensate for the east-west stretching or compression, giving an equal-area map.
- ✓ Lambert conformal conic, which adjusts the north-south distance between non-standard parallels to equal the east-west stretching, giving a conformal map.

Pseudoconic

- ***Bonne***, an equal-area projection on which most meridians and parallels appear as curved lines. It has a configurable standard parallel along which there is no distortion.
- ***Werner cordiform***, upon which distances are correct from one pole, as well as along all parallels. ***American polyconic***





AmericanPolyconic/Polyconic

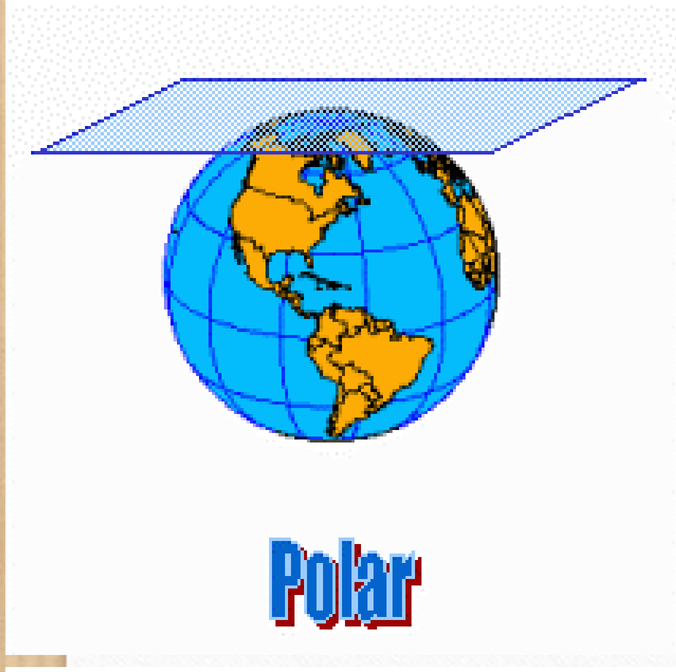
Planar or Azimuthal Projection

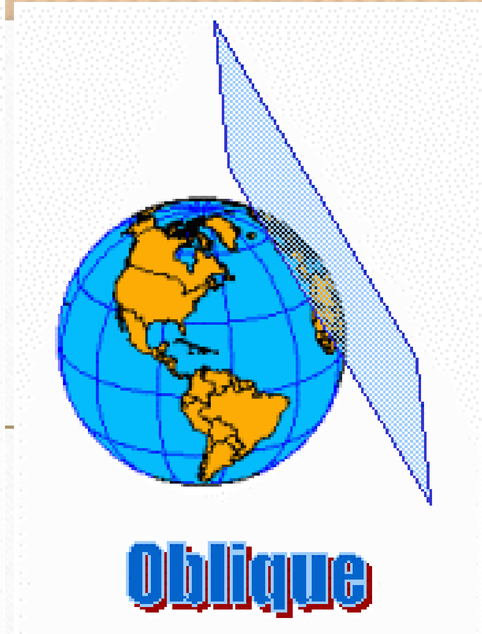
Azimuthal projections have the property that directions from a central point are preserved and therefore great circles through the central point are represented by straight lines on the map.

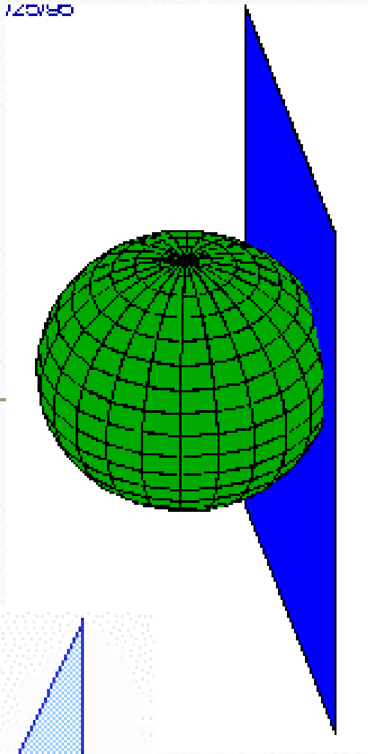
These projections also have radial symmetry in the scales and hence in the distortions: map distances from the central point are computed by a function r(d) of the true distance d, independent of the angle.

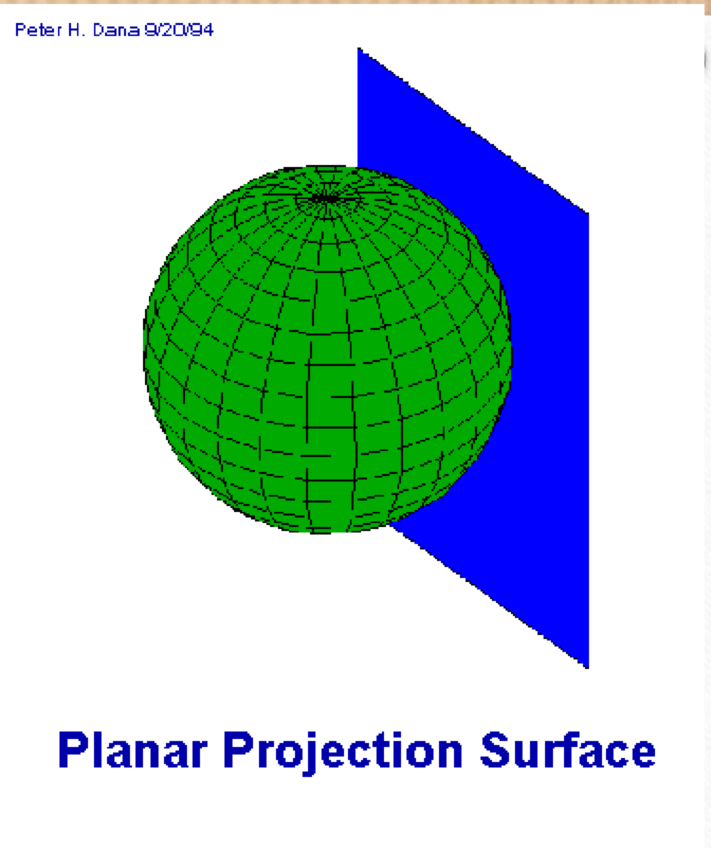
The radial scale is r′(d) and the transverse scale $\frac{r(d)}{R\sin(d/R)}$ where R is the radius of the Earth.

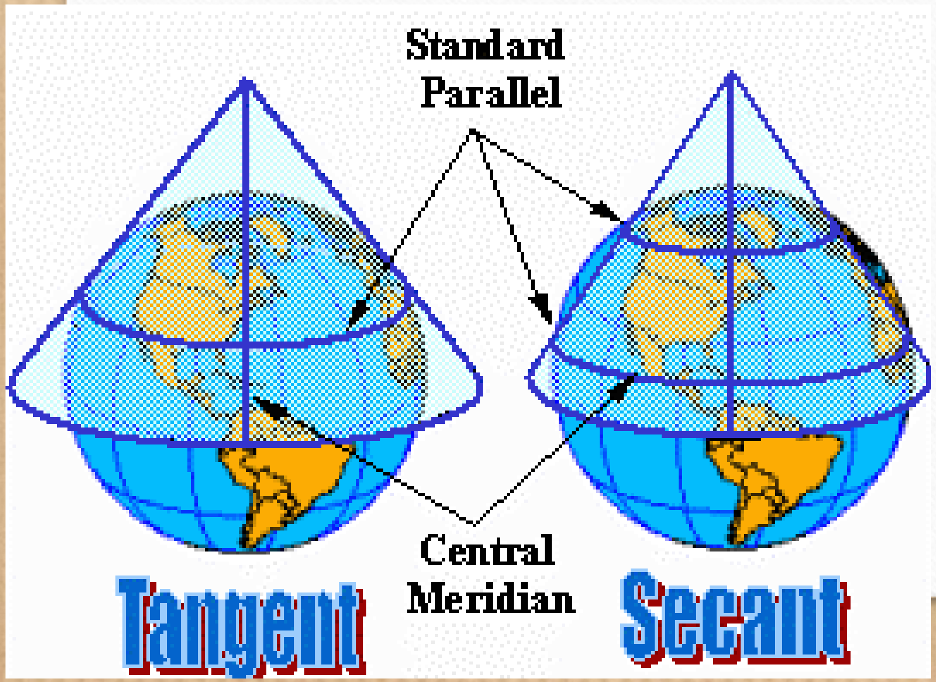
- ✓Projecting spherical surface onto a plane that is tangent to a reference point on globe.
- ✓If the plane touches north or south pole then the projection is called polar azimuthal.
- ✓Called normal if reference point is on the equator.
- ✓Oblique for all other reference points.

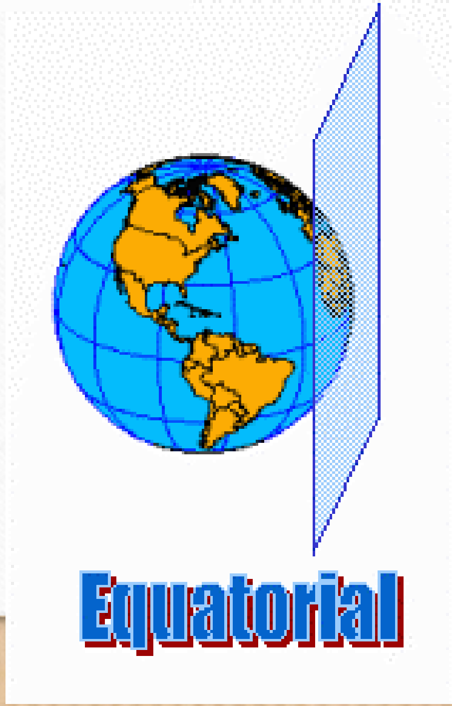

Polar


Oblique




Peter H. Dana 9/20/94
Planar Projection Surface

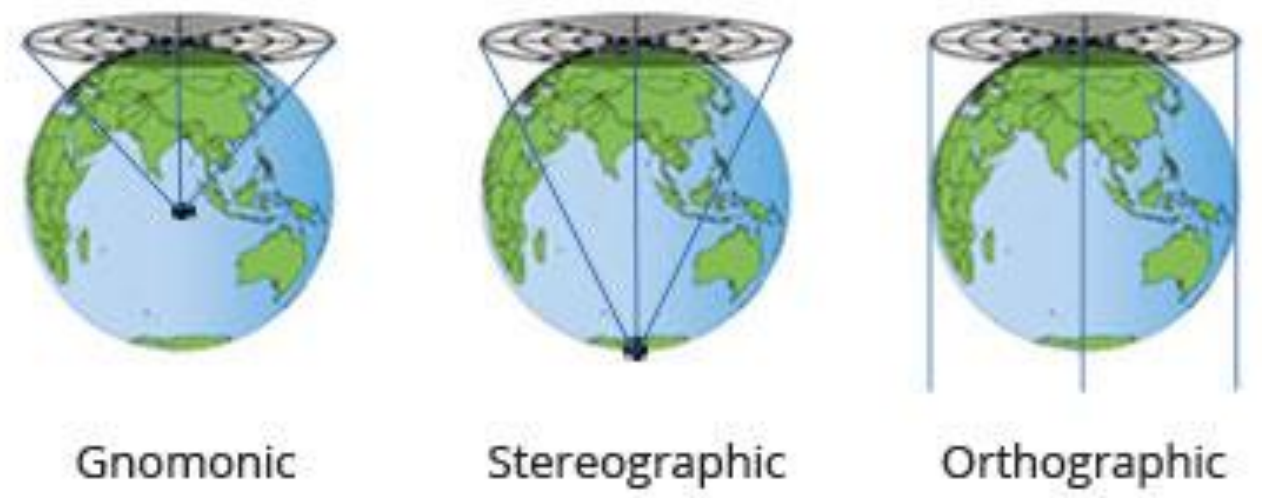

Standard Parallel
Central Meridian
Tangent
Secant


Equatorial

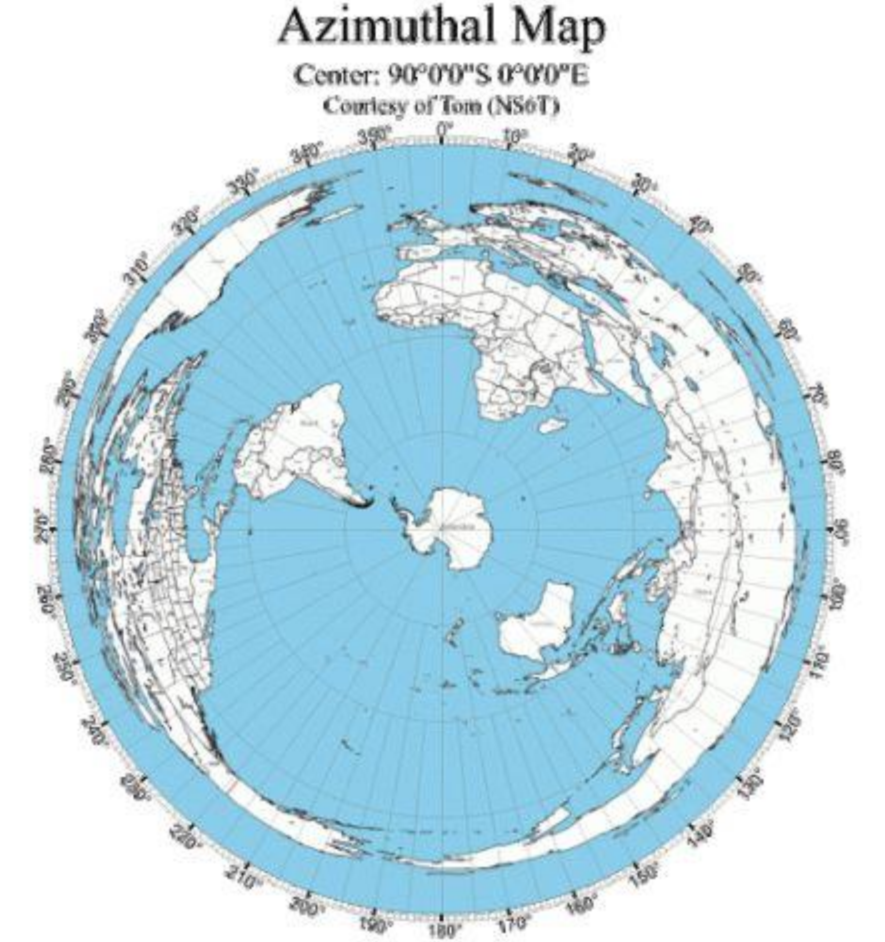
- The gnomonic projection displays great circles as straight lines. Can be constructed by using a point of perspective at the center of the Earth. $r(d) = c \tan (d/R)$.

- The orthographic projection maps each point on the earth to the closest point on the plane. Can be constructed from a point of perspective an infinite distance from the tangent point; $r(d) = c \sin (d/R)$. Can display up to a hemisphere on a finite circle. Photographs of Earth from far enough away, such as the Moon, approximate this perspective.

- The stereographic projection, which is conformal, can be constructed by using the tangent point's antipode as the point of perspective. $r(d) = c \tan d/2R$; the scale is $c/(2R \cos^2 d/2R)$. Can display nearly the entire sphere's surface on a finite circle. The sphere's full surface requires an infinite map.

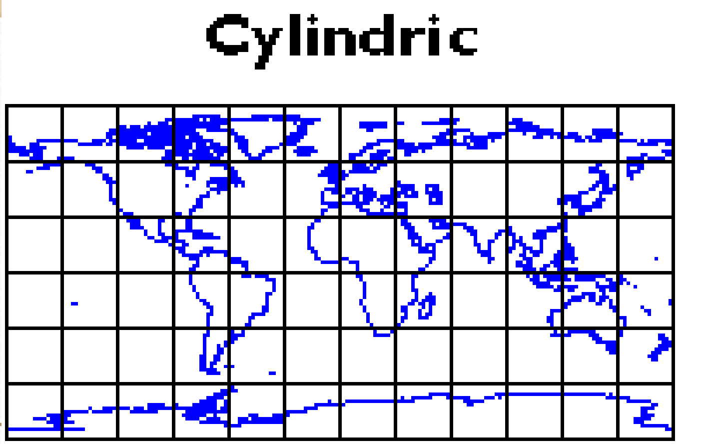


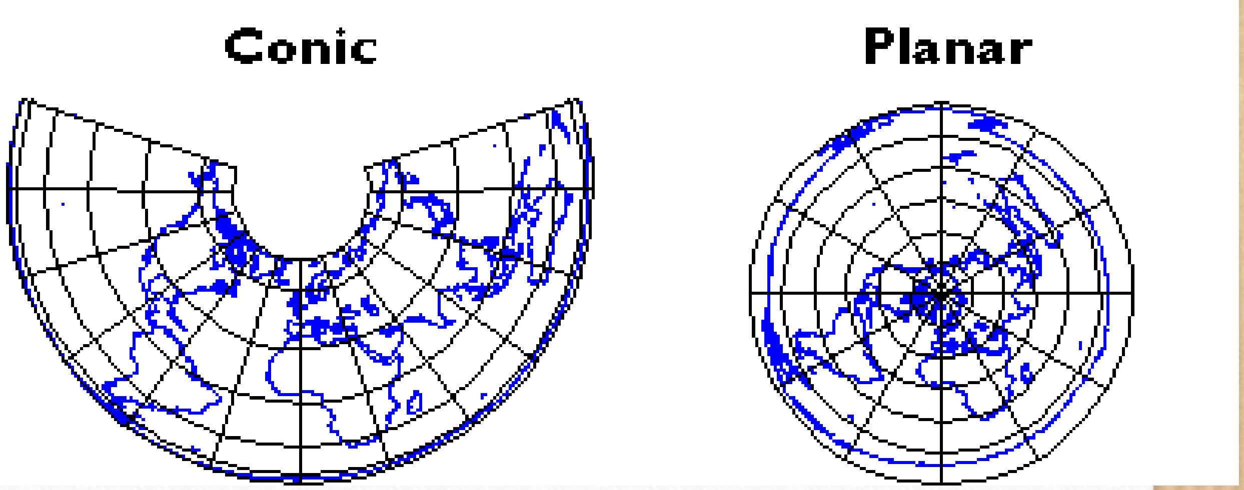
Azimuthal projections

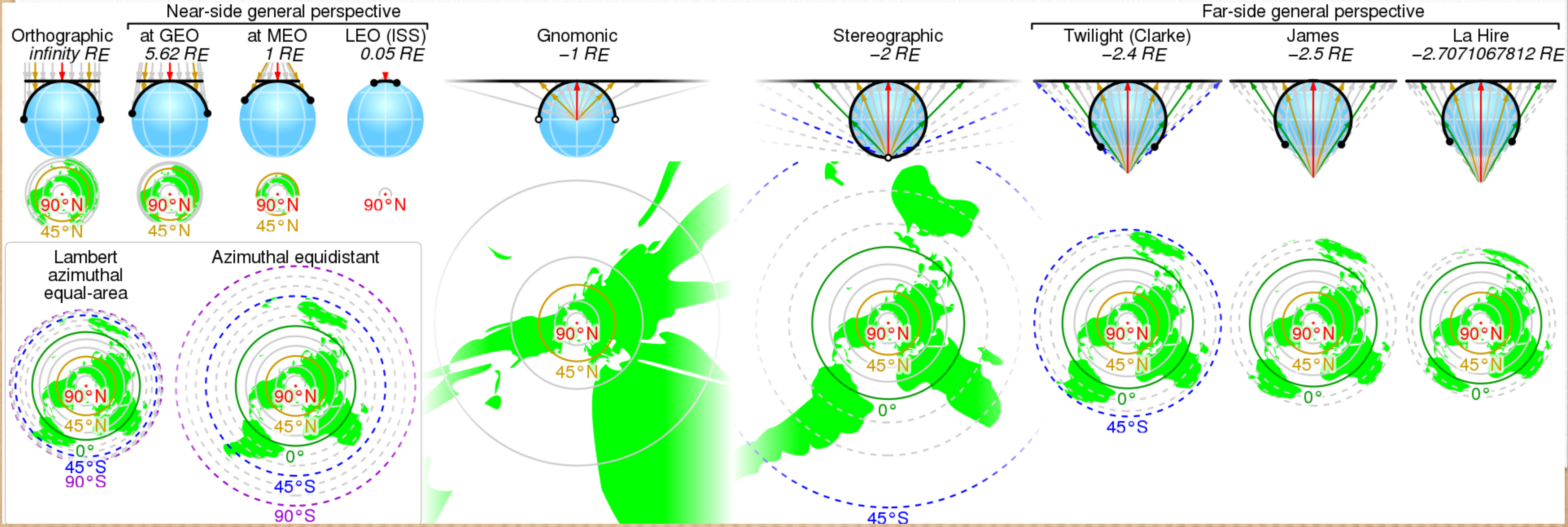


Other azimuthal projections are not true perspective projections:

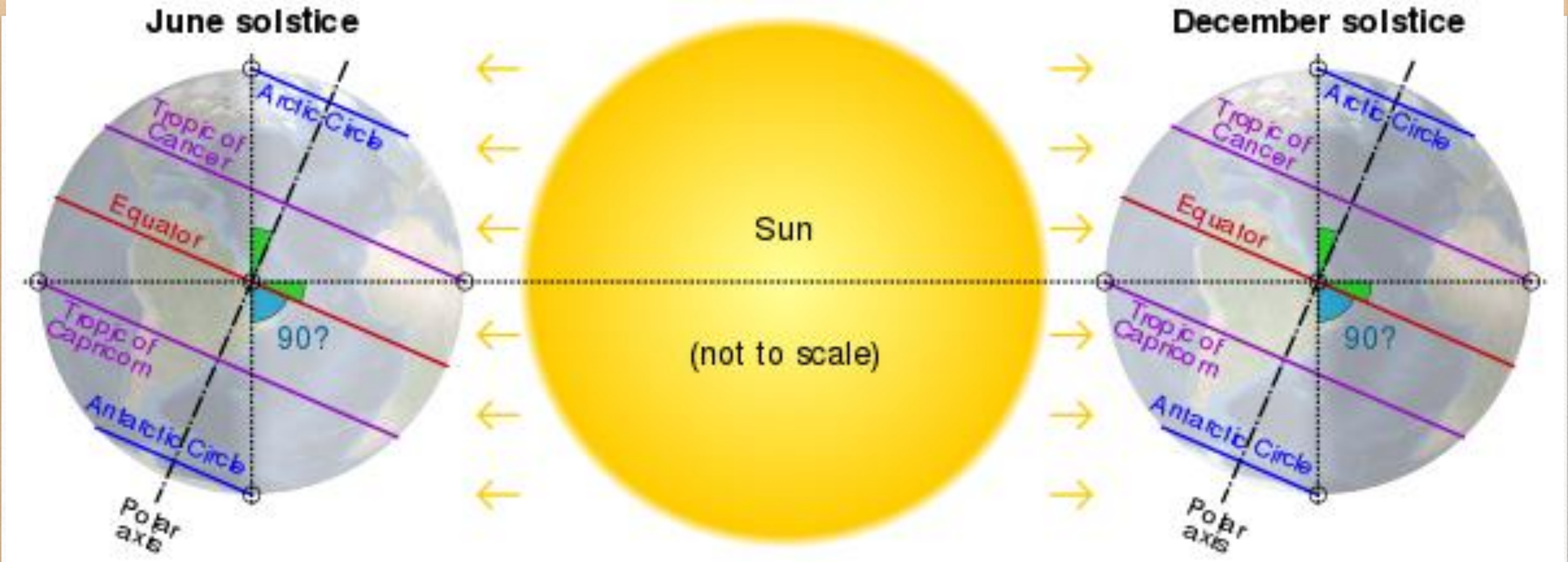
- Azimuthal equidistant: $r(d) = cd$; it is used by amateur radio operators to know the direction to point their antennas toward a point and see the distance to it. Distance from the tangent point on the map is proportional to surface distance on the earth (the tangent point is the North Pole, flag of the United Nations)
- Lambert azimuthal equal-area. Distance from the tangent point on the map is proportional to straight-line distance through the earth: $r(d) = c \sin d/2R$
- Logarithmic azimuthal is constructed so that each point's distance from the center of the map is the logarithm of its distance from the tangent point on the Earth. $r(d) = c \ln d/d_0$); locations closer than at a distance equal to the constant d_0 are not shown.


Cylindric


Conic
Planar


Near-side general perspective
Orthographic
infinity RE
at GEO
5.62 RE
at MEO
1 RE
LEO (ISS)
0.05 RE
Gnomonic
−1 RE
Stereographic
−2 RE
Far-side general perspective
Twilight (Clarke)
−2.4 RE
James
−2.5 RE
La Hire
−2.7071067812 RE
90°N
45°N
0°
45°S
90°S
Lambert
azimuthal
equal-area
Azimuthal equidistant

Cylindrical	straight parallels; straight meridians
Pseudo-cylindrical	straight parallels, curved meridians
Conic	partial concentric circles for parallels; straight meridians
Pseudo-conic	partial concentric circles for parallels; curved meridians
Planar	Concentric circles for parallels; straight meridians
Modified planar	No common appearance of parallels and meridians



- Arctic Circle (66°33′47.7″ N)
- Tropic of Cancer (23°26′12.3″ N)
- Equator (0° latitude)
- Tropic of Capricorn (23°26′12.3″ S)
- Antarctic Circle (66°33′47.7″ S)

Measurement

Module 3 Lecture 1

Thank You