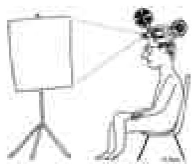
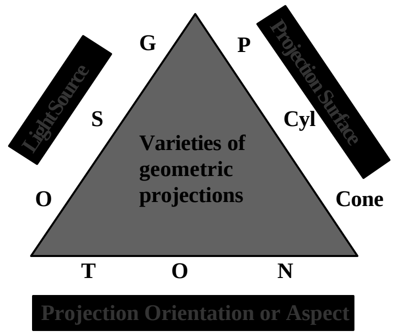
Map Projections



Map Projection

- Scientific method of transferring locations on Earth's surface to a flat map
- 3 major families of projection
  - Cylindrical
    - Mercator Projection
  - Conic Projections
    - Well suited for mid-latitudes
  - Planar Projections

The Variables in Map Projection



We will come back to this graphic later in the lecture

Map Projection Distorts Reality

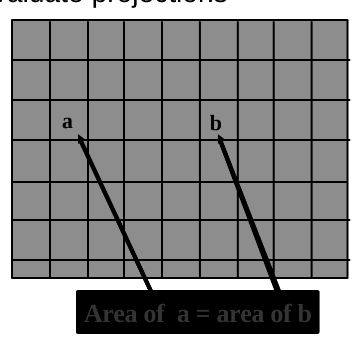
- A sphere is not a **developable solid**.
- Transfer from 3D globe to 2D map **must** result in loss of one or global characteristics:
  - Shape
  - Area
  - Distance
  - Direction
  - Position

Characteristics of a **<u>Globe</u>** to consider as you evaluate projections

- Scale is everywhere the same:
  - all **great circles** are the same length
  - the poles are **points.**
- Meridians are spaced evenly along parallels.
- Meridians and parallels cross at right angles.

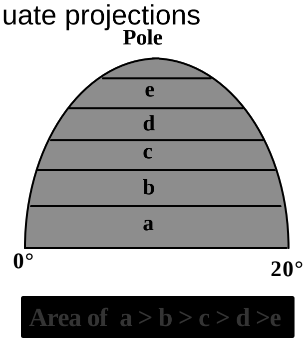
Characteristics of globe to consider as you evaluate projections

- Quadrilaterals equal in longitudinal extent formed between two parallels have **equal area.**



Characteristics of globe to consider as you evaluate projections

- Areas of quadrilaterals formed by any two meridians and sets of evenly spaced parallels decrease poleward.



Classification of Projections:

- What global characteristic preserved.
- Geometric approach to construction.
  - projection surface
  - “light” source
- Orientation.
- Interface of projection surface to Earth.

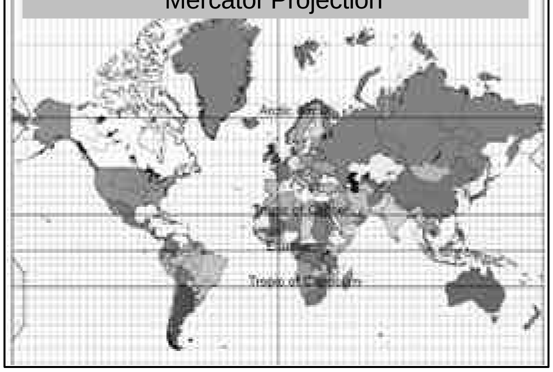
Global Characteristic Preserved

- Conformal
- Equivalent
- Equidistant
- Azimuthal or direction

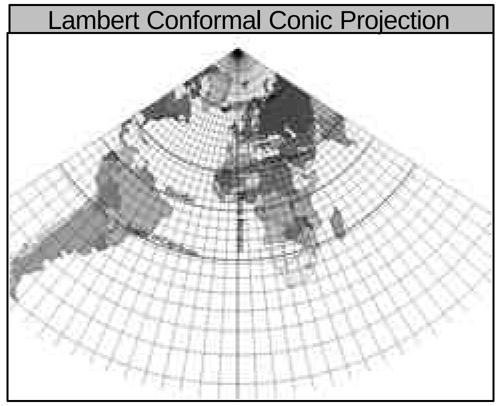
Conformal Projections

- Retain correct angular relations in transfer from globe to map.
- Angles correct for small areas.
- Scale same in any direction around a point, **but** scale changes from point to point.
- Parallels and meridians cross at right angles.
- Large areas tend to look more like they do on the globe than is true for other projections.
- Examples: Mercator and Lambert Conformal Conic

Mercator Projection



Lambert Conformal Conic Projection



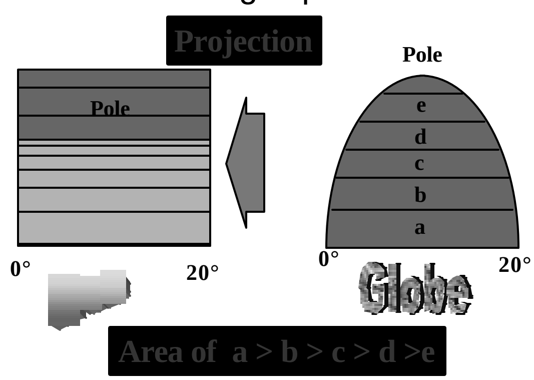
Equivalent or Equal Area Projections

- A **map area of a given size**, a circle three inches in diameter for instance, **represents same amount of Earth space** no matter where on the globe the map area is located.

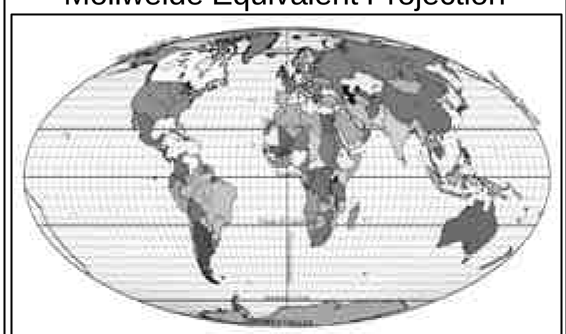
Equivalent or Equal Area Projections

- A **map area of a given size**, a circle three inches in diameter for instance, **represents same amount of Earth space** no matter where on the globe the map area is located.
- Maintaining equal area requires:
  - Scale changes in ***one direction*** to be offset by scale changes in the ***other direction.***
  - Right angle crossing of meridians and parallels often lost, resulting in shape distortion.

Maintaining Equal Area



Mollweide Equivalent Projection

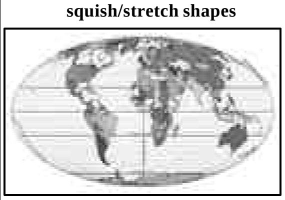


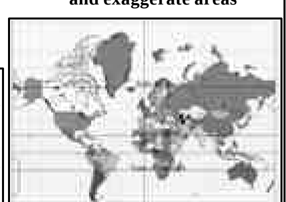
Equivalent & Conformal

OR

Preserve true shapes and exaggerate areas

Show true size and squish/stretch shapes



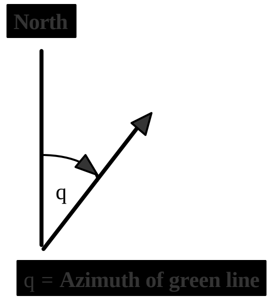


Equidistant Projections

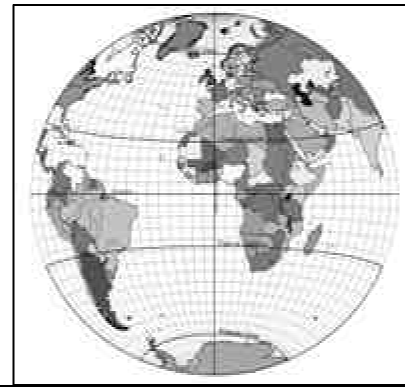
- Length of a straight line between two points represents correct great circle distance.
- Lines to measure distance can ***originate at only one or two points.***

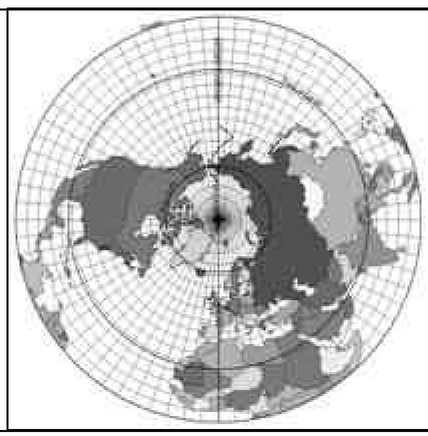
Azimuthal Projections

- Straight line drawn between two points depicts correct:
  - Great circle route
  - Azimuth
    - Azimuth = angle between starting point of a line and north
- Line can originate from only one point on map.

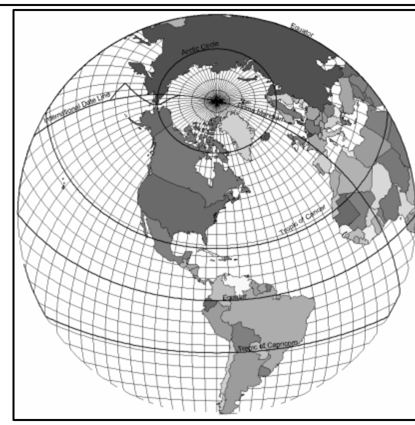


Plane Projection: Lambert Azimuthal Equal Area





Azimuthal Projection Centered on Rowan

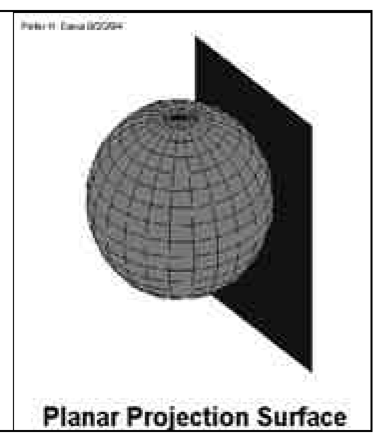


Projections Classified by Projection Surface & Light Source

- Developable surface (transfer to 2D surface)
  - Common surfaces:
    - Plane
    - Cone
    - Cylinder
- Light sources:
  - Gnomonic
  - Stereographic
  - Orthographic

Plane Surface

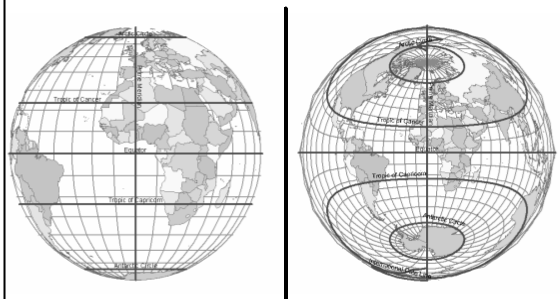
- Earth grid and features projected from sphere to a plane surface.



Plane Projection

- Equidistant
- Azimuthal

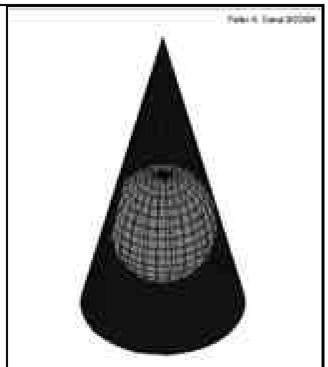
Plane Projection: Lambert Azimuthal Equal Area



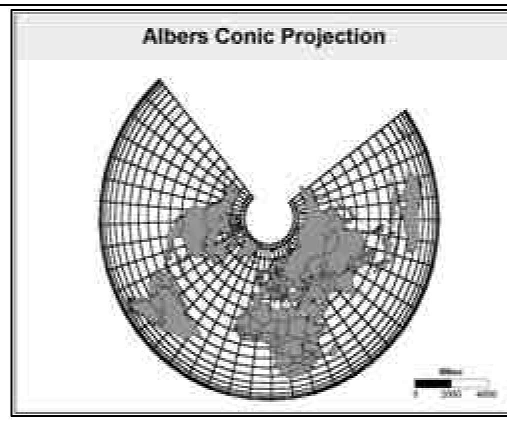
Globe Projection to plane

Conic Surface

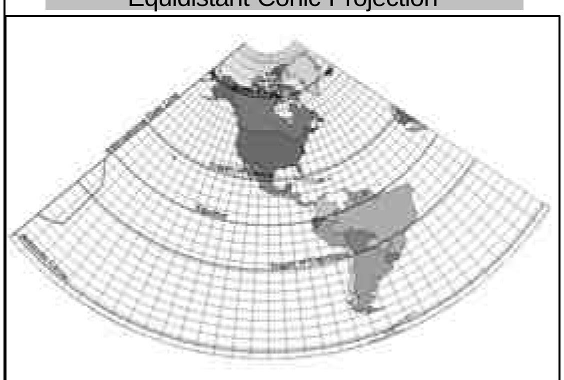
- Globe projected onto a cone, which is then flattened.
- Cone usually fit over pole like a dunce cap.
  - Meridians are straight lines.
  - Angle between all meridians is identical.



Conical Projection Surface

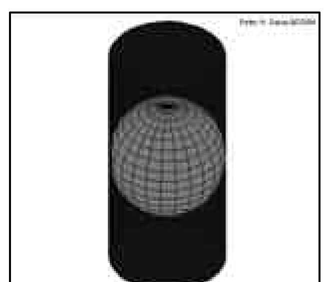


Equidistant Conic Projection



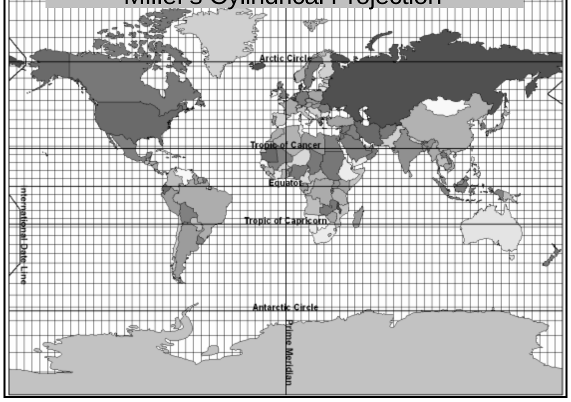
Cylinder Surface

- Globe projected onto a cylinder, which is then flattened.
- Cylinder usually fit around equator.
  - Meridians are evenly spaced straight lines.
  - Spacing of parallels varies depending on specific projection.



Cylindrical Projection Surface

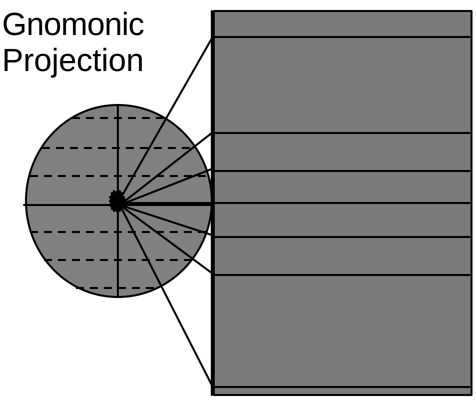
Miller's Cylindrical Projection



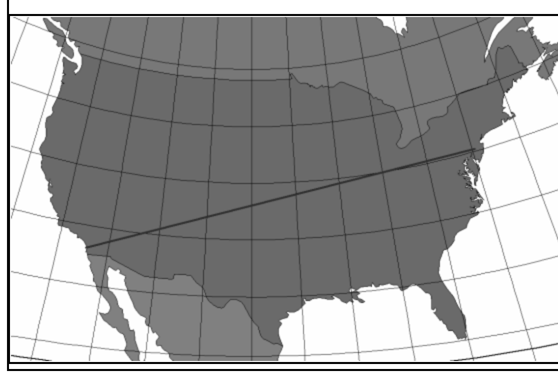
"Light" Source Location

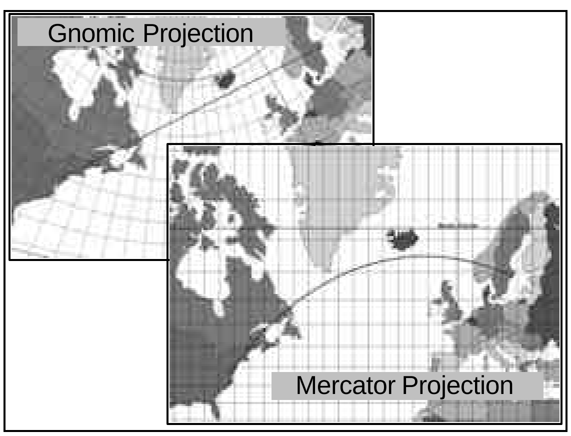
- **Gnomonic:** light projected from ***center of globe*** to projection surface.
- **Stereographic:** light projected from ***antipode*** **of point of tangency.**
- **Orthographic:** light projected from ***infinity***.

Gnomonic Projection

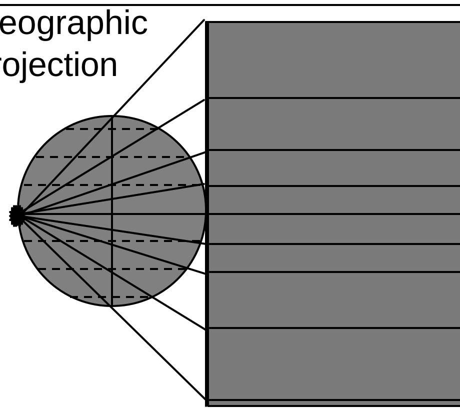


Gnomic Projection

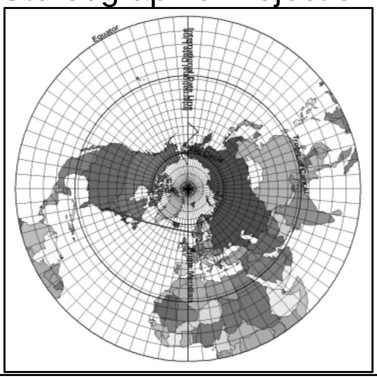




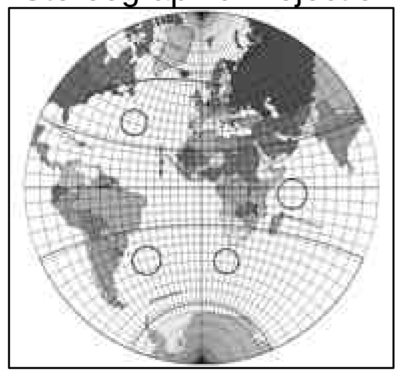
Stereographic Projection



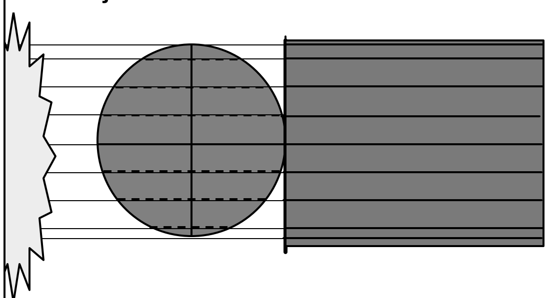
Stereographic Projection

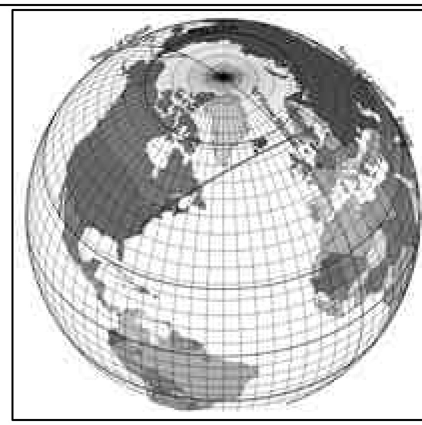


Stereographic Projection



Orthographic Projection

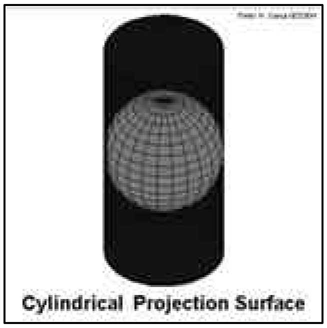




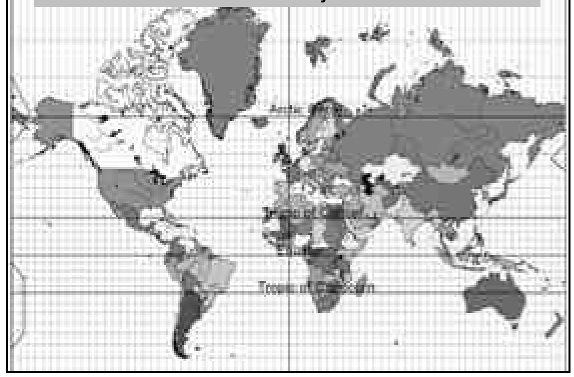
Projection Orientation

- **Orientation:** the position of the **point or line of tangency** with respect to the globe.
- **Normal** orientation or aspect: usual orientation for the developable surface: equator for cylinder, pole for plane, apex of cone over pole for cone [parallel].
- **Transverse** or polar aspect:
  - point of tangency at equator for plane.
  - line of tangency touches pole as it wraps around earth for cylinder.
  - Hardly done for cone
- **Oblique** aspect: the point or line of tangency is anywhere but the pole or the equator.

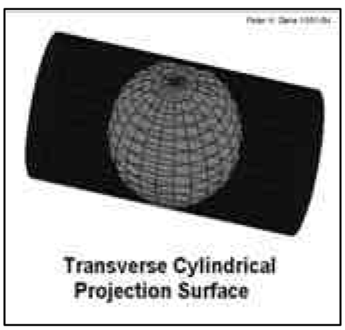
Normal Orientation

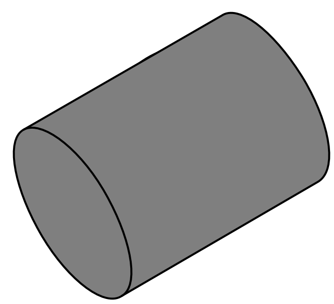


Mercator Projection

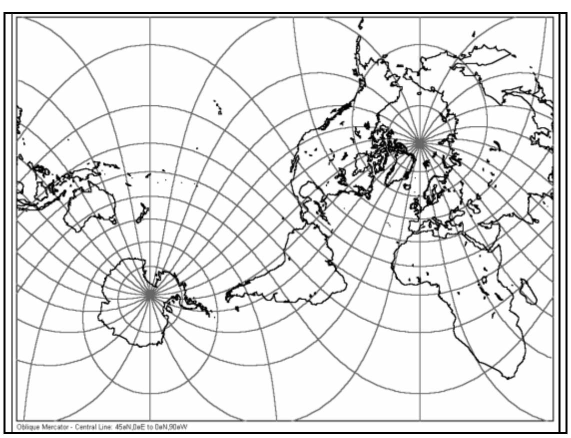


Transverse Orientation

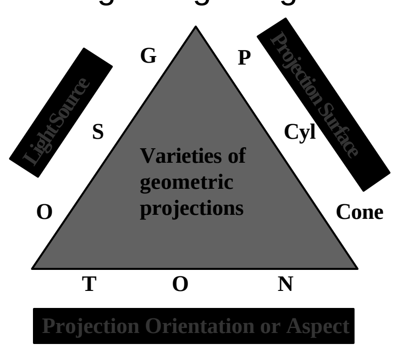




Oblique Orientation



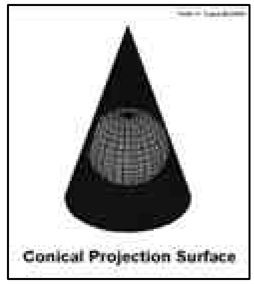
Putting Things Together

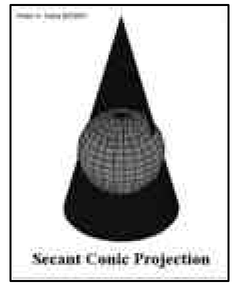


Projection Surface to Globe Interface

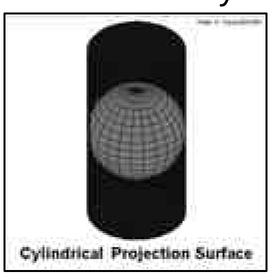
- **Any of the various possible projection combinations can have either a tangent or a secant interface:**
  - **Tangent:** projection surface ***touches*** globe **surface** at one point or along one line.
  - **Secant:** projection surface ***intersects*** the globe thereby defining a:
    - Circle of contact in the case of a plane,
    - Two lines of contact and hence true scale in the case of a cone or cylinder.

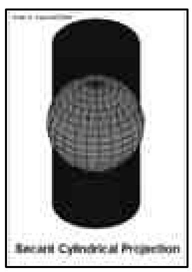
Tangent & Secant Projections: Cone





Tangent & Secant Projections: Cylinder





Projection Selection Guidelines

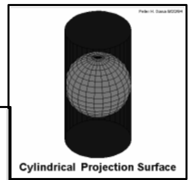
- Determine which global feature is most important to preserve [e.g., shape, area].
- Where is the place you are mapping:
  - Equatorial to tropics = consider cylindrical
  - Midlatitudes = consider conic
  - Polar regions = consider azimuthal
- Consider use of secant case to provide two lines of zero distortion.

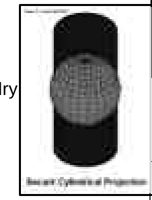
Example Projections & Their Use

- Cylindrical
- Conic
- Azimuthal
- Nongeometric or mathematical

Cylindrical Projections

Cylindrical Projections





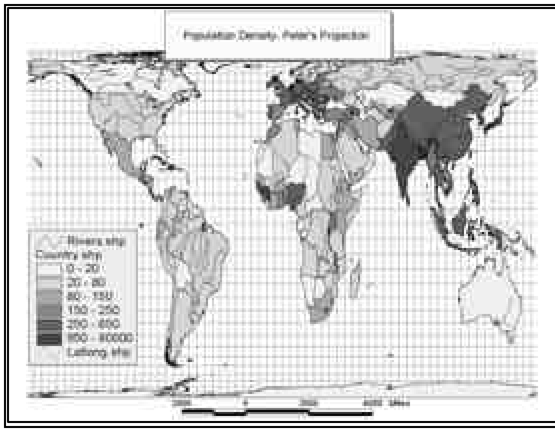
- Equal area:
  - Cylindrical Equal Area
  - Peters [wet laundry map].
- Conformal:
  - Mercator
  - Transverse Mercator
- Compromise:
  - Miller

Cylindrical Projections

- Cylinder wrapped around globe:
  - Scale factor = 1 at equator [normal aspect]
  - Meridians are evenly spaced. As one moves poleward, equal longitudinal distance on the map represents **less and less** distance on the globe.
  - Parallel spacing varies depending on the projection. For instance different light sources result in different spacing.

Peter's Projection

- Cylindrical
- Equal area

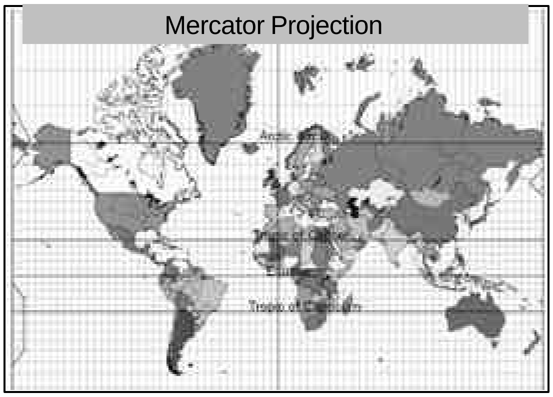


Central Perspective Cylindrical

- Light source at center of globe.
  - Spacing of parallels increases rapidly toward poles. Spacing of meridians stays same.
    - Increase in north-south scale toward poles.
    - Increase in east-west scale toward poles.
  - Dramatic area distortion toward poles.

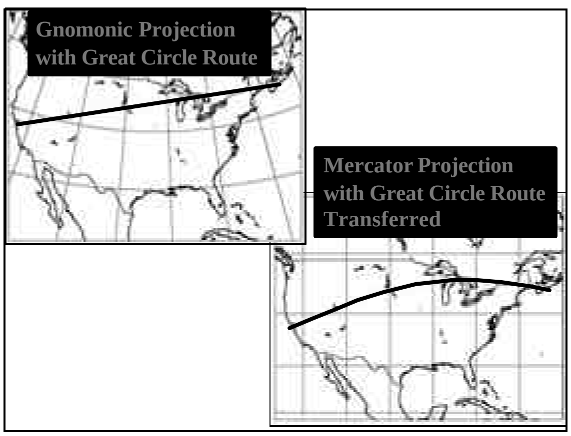
Mercator Projection

- Cylindrical like mathematical projection:
  - Spacing of parallels increases toward poles, but more slowly than with central perspective projection.
  - North-south scale increases at the same rate as the east-west scale: scale is the same around any point.
  - Conformal: meridians and parallels cross at right angles.
- Straight lines represent lines of constant compass direction: loxodrome or rhumb lines.



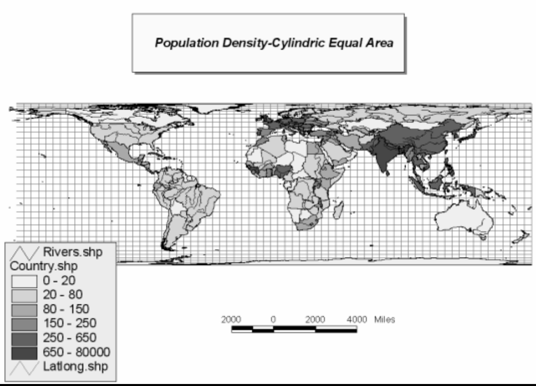
Gnomonic Projection

- **Geometric azimuthal** projection with light source at center of globe.
  - Parallel spacing increases toward poles.
  - Light source makes depicting entire hemisphere impossible.
- Important characteristic: straight lines on map represent **great circles** on the globe.
- Used with Mercator for navigation :
  - Plot great circle route on Gnomonic.
  - Transfer line to Mercator to get plot of required compass directions.



Cylindrical Equal Area

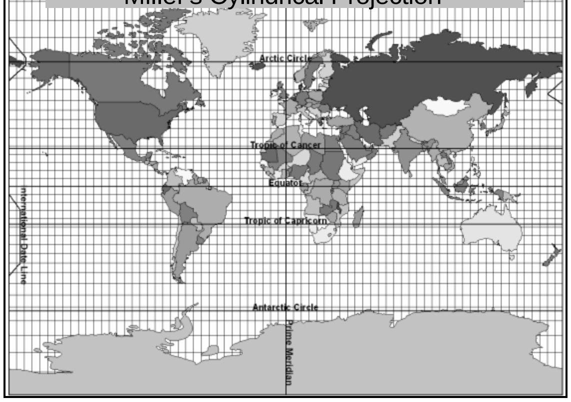
- Light source: orthographic.
- Parallel spacing decreases toward poles.
- Decrease in N-S spacing of parallels is exactly offset by increase E-W scale of meridians. Result is equivalent projection.
- Used for world maps.



Miller's Cylindrical

- Compromise projection→ near conformal
- Similar to Mercator, but less distortion of area toward poles.
- Used for world maps.

Miller's Cylindrical Projection



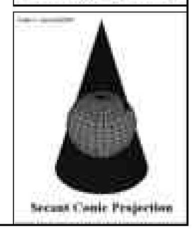
Conic Projections

Conics

- Globe projected onto a cone, which is then opened and flattened.
- Chief differences among conics result from:
  - Choice of standard parallel.
  - Variation in spacing of parallels.
- Transverse or oblique aspect is possible, but rare.
- All polar conics have straight meridians.
- Angle between meridians is identical for a given ***standard parallel*** .

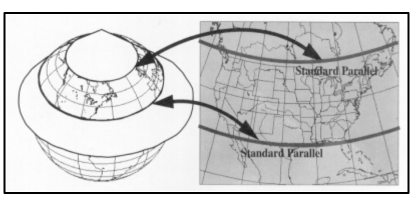
Conic Projections

- Equal area:
  - Albers
  - Lambert
- Conformal:
  - Lambert



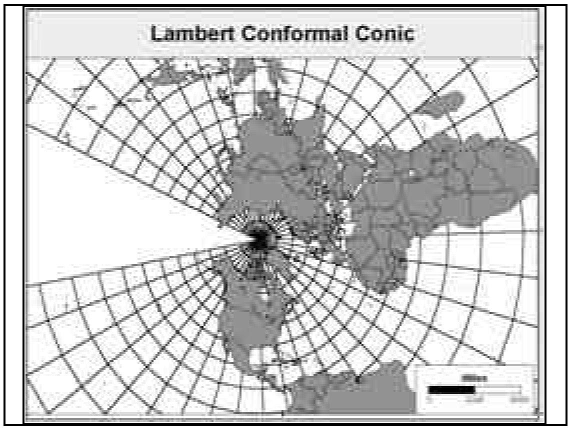
Conic Projections

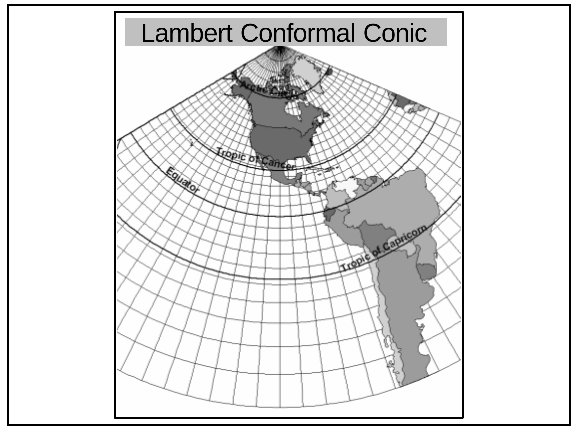
- Usually drawn secant.
- Area between standard parallels is “projected” inward to cone.
- Areas outside standard parallels projected



Lambert Conformal Conic

- Parallels are arcs of concentric circles.
- Meridians are straight and converge on one point.
- Parallel spacing is set so that N-S and E-W scale factors are equal around any point.
- Parallels and meridians cross at right angles.
- Usually done as secant interface.
- Used for conformal mapping in mid-latitudes for maps of great east-west extent.



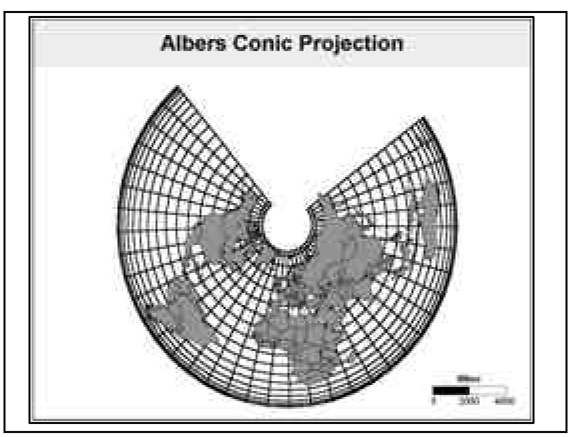


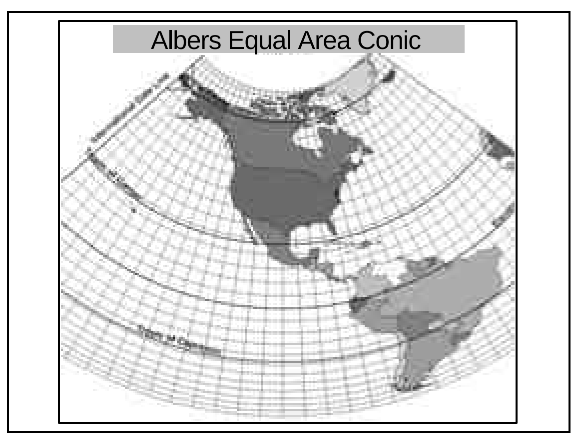
Albers Equal Area Conic

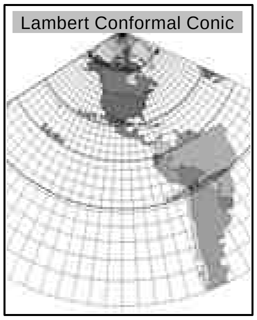
- Parallels are concentric arcs of circles.
- Meridians are straight lines drawn from center of arcs.
- Parallel spacing adjusted to offset scale changes that occur between meridians.
- Usually drawn secant.
  - Between standard parallels E-W scale too small, so N-S scale increased to offset.
  - Outside standard parallels E-W scale too large, so N-S scale is decreased to compensate.

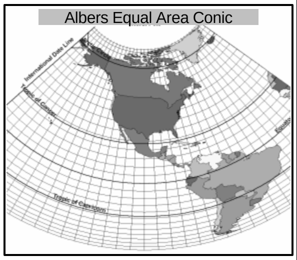
Albers Equal Area Conic

- Used for mapping regions of great east-west extent.
- Projection is equal area and yet has very small scale and shape error when used for areas of small ***latitudinal*** extent.



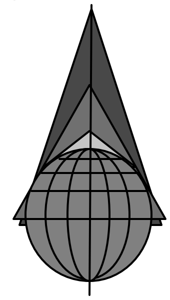


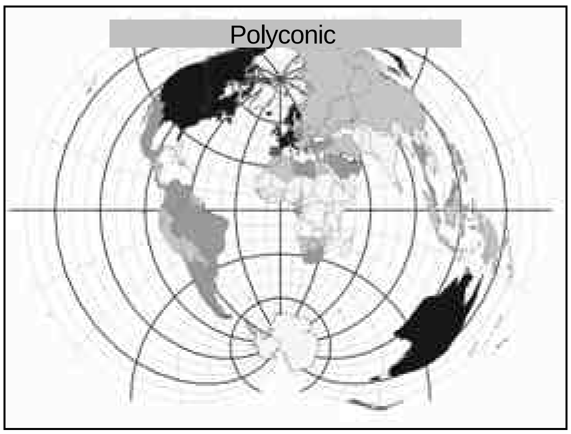




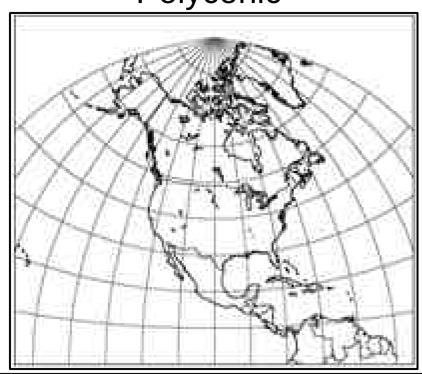
Modified Conic Projections

- Polyconic:
  - Place multiple cones over pole.
  - Every parallel is a standard parallel.
  - Parallels intersect central meridian at true spacing.
  - Compromise projection with small distortion near central meridian.





Polyconic



Azimuthal Projections

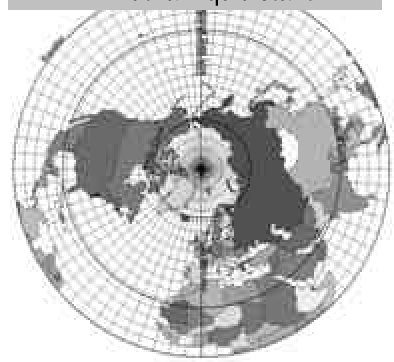
Azimuthal Projections

- Equal area:
  - Lambert
- Conformal:
  - Sterographic
- Equidistant:
  - Azimuthal Equidistant
- Gnomonic:
  - Compromise, but all straight lines are great circles.

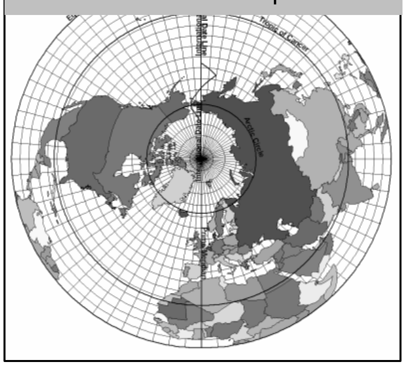
Azimuthal Projections

- Projection to the plane.
- All aspects: normal, transverse, oblique.
- Light source can be gnomonic, stereographic, or orthographic.
- Common characteristics:
  - great circles passing through point of tangency are straight lines radiating from that point.
  - these lines all have correct compass direction.
  - points equally distant from center of the projection on the ***globe*** are equally distant from the center of the ***map.***

Azimuthal Equidistant



Lambert Azimuthal Equal Area



Other Projections

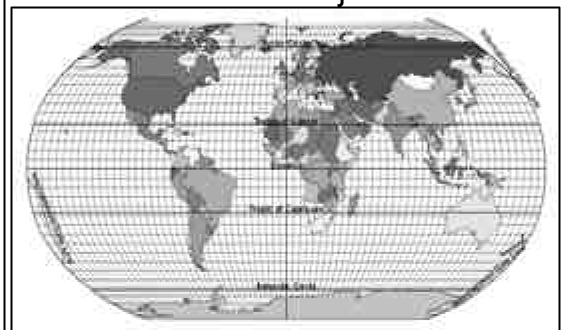
Other Projections

- Not strictly of a development family
- Usually “compromise” projections.
- Examples:
  - Van der Griten
  - Robinson
  - Mollweide
  - Sinusodial
  - Goode’s Homolosine
  - Briesmeister
  - Fuller

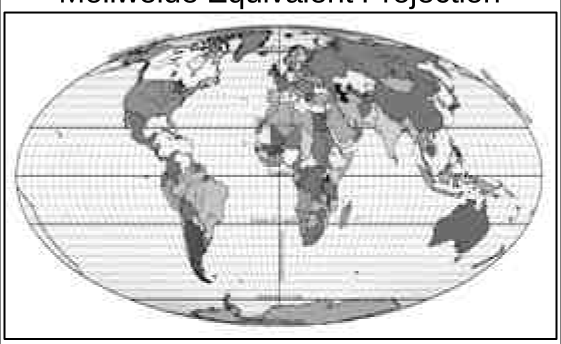
Van der Griten

Van der Griten

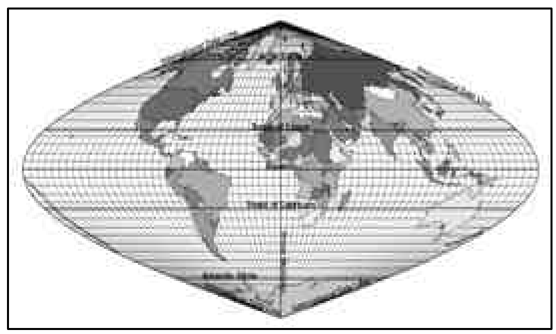
Robinson Projection

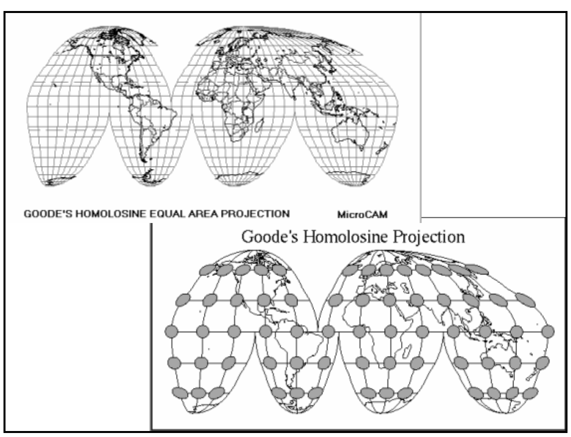


Mollweide Equivalent Projection



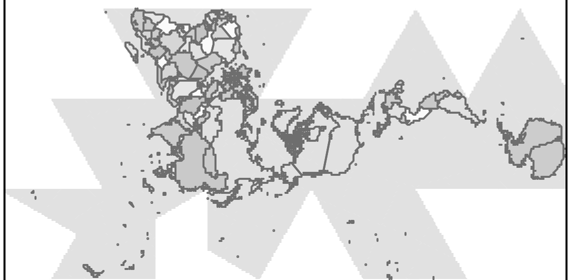
Sinusoidal Equal Area Projection





Briemeister

Fuller Projection



Projections & Coordinate Systems for Large Scale Mapping