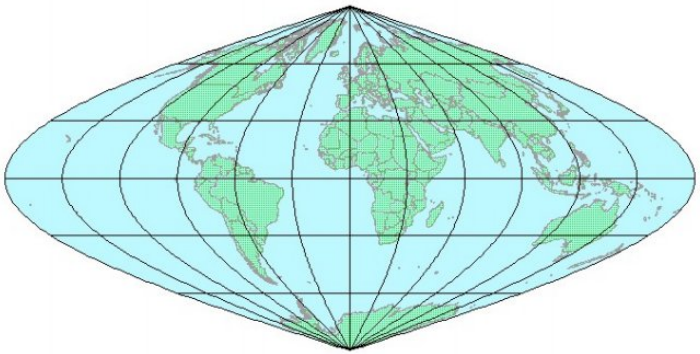
Using Projections to Map the Earth

- We have discussed **geodesy**, and we now know about modeling the shape of Earth as an ellipsoid and geoid
- We are ready to tackle the problem of transforming the **3-dimensional Earth → 2-dimensional representation** that suits our purposes:

Earth surface

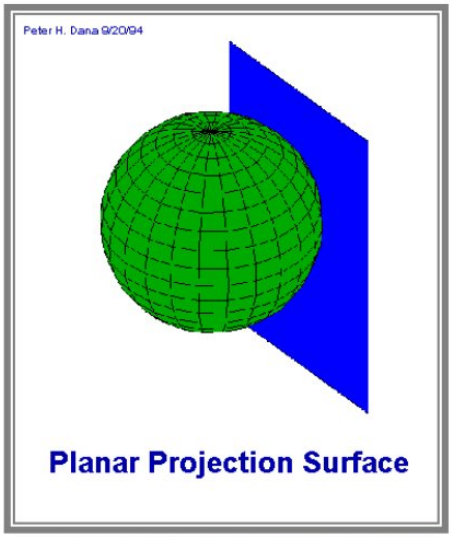
map

Paper map or GIS

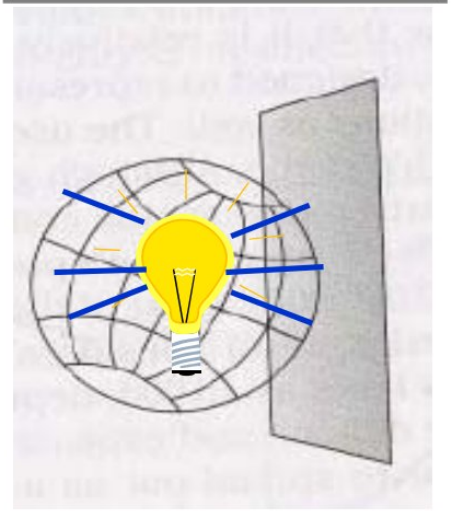


What is a Projection?

- **Map projection** - The systematic transformation of points on the **Earth's surface** to corresponding points on a **planar surface**

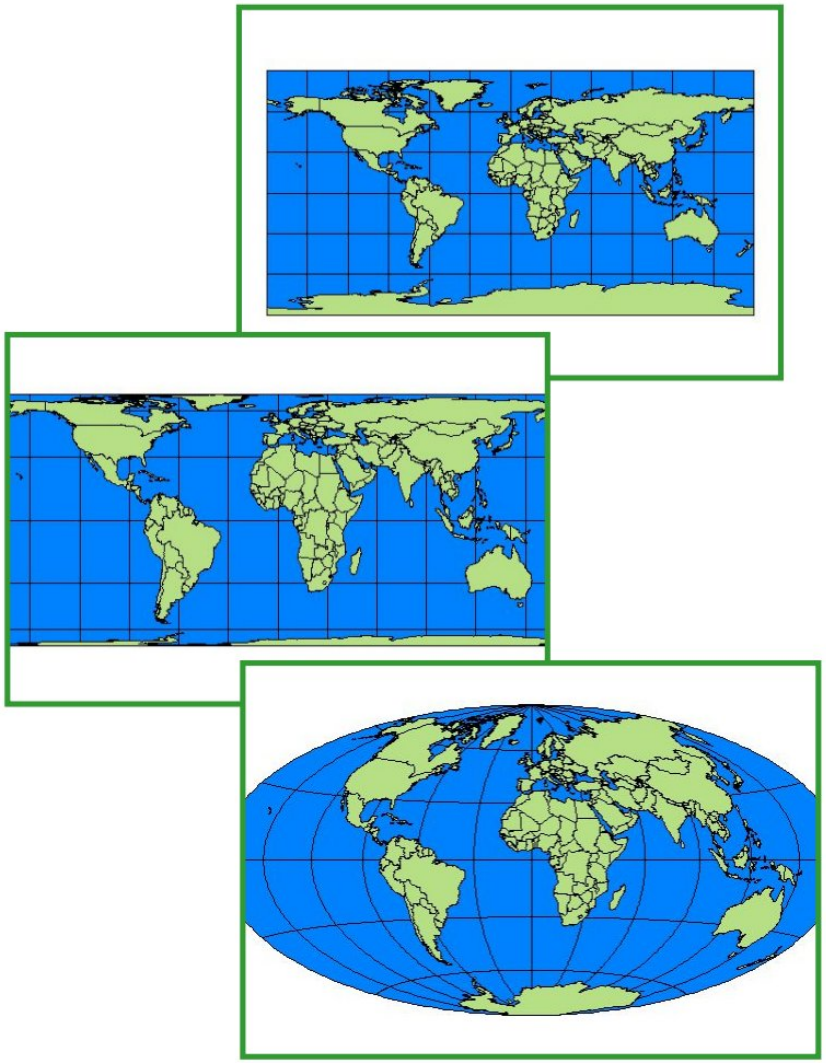


•The easiest way to imagine this is to think of a **light bulb** inside of a semi-transparent globe, shining features from the **Earth's surface** onto the **planar surface**



Projections Distort

- Because we are going from the 3D Earth → 2D planar surface, projections **always** introduce some type of **distortion**
- When we select a map projection, we choose a particular projection to **minimize the distortions** that are important to a **particular application**



Three Families of Projections

- There are **three major families** of projections, each tends to introduce **certain kinds of distortions**, or conversely each has certain **properties** that it used to **preserve** (i.e. spatial characteristics that it does not distort):
- **Three families:**
  1. Cylindrical projections
  2. Conical projections
  3. Planar projections

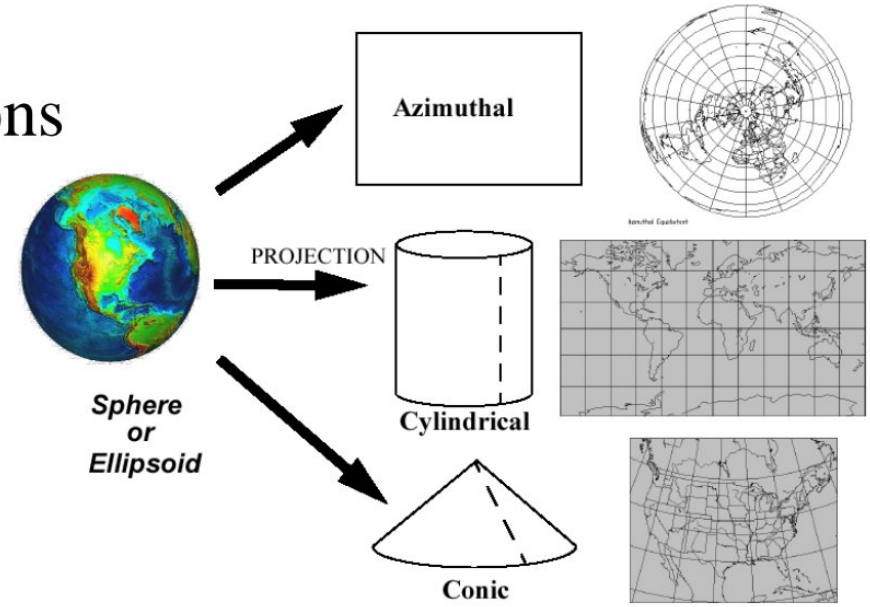
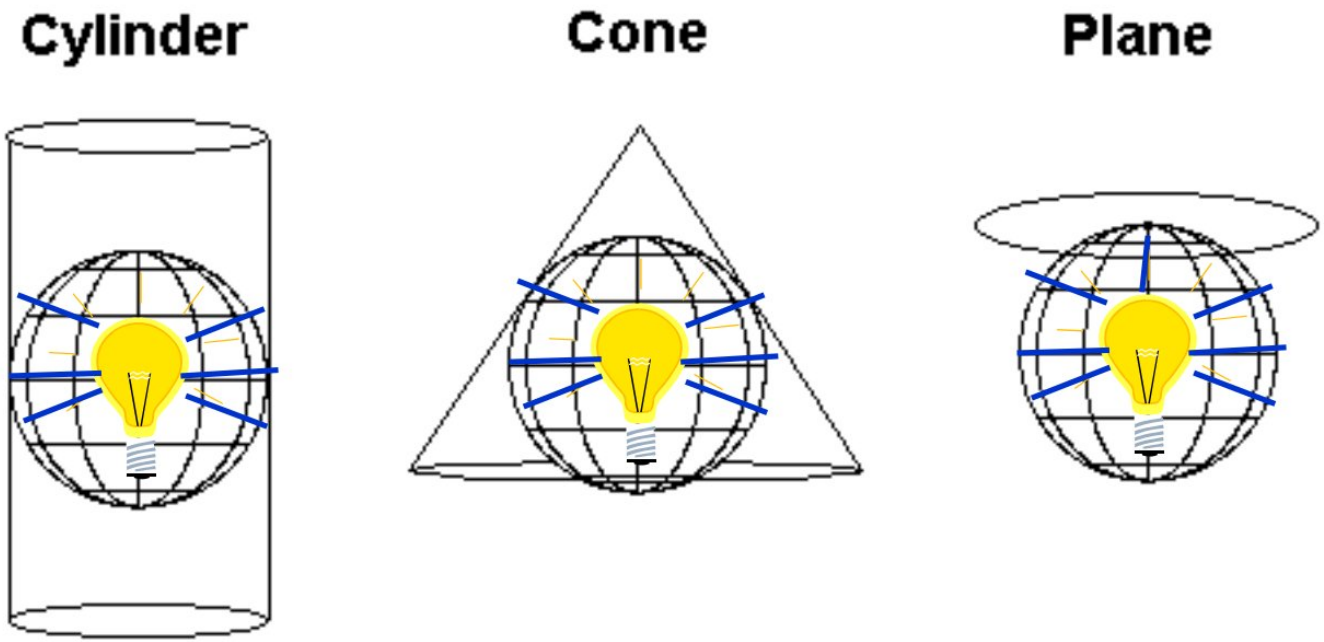


Figure 2.7 The earth can be projected in many ways, but basically onto three shapes that can be unrolled into a flat map: a flat plane, a cylinder, and a cone.

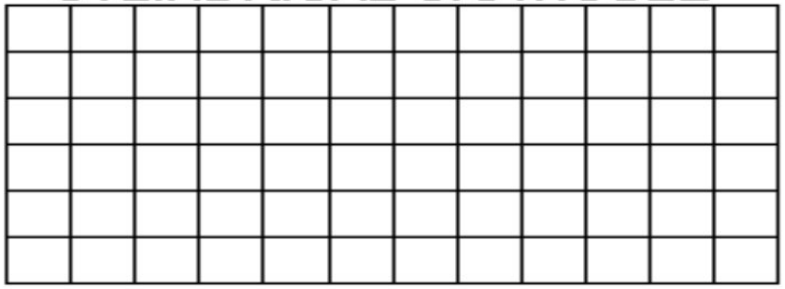
The Graticule

- Picture a light source **projecting** the shadows of the graticule lines on the surface of a transparent globe onto the developable surface …

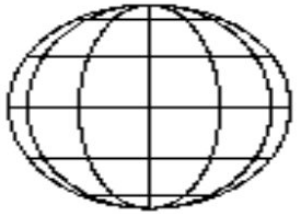


The Graticule, Projected

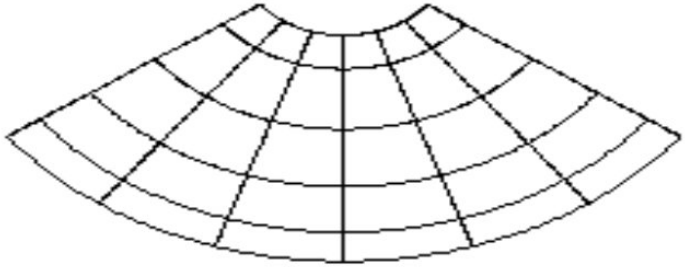
CYLINDRICAL GRATICULE



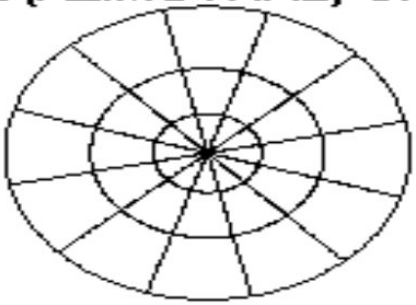
GLOBE GRATICULE



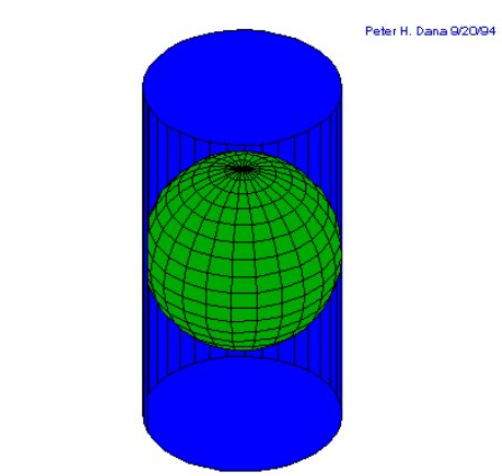
CONIC GRATICULE



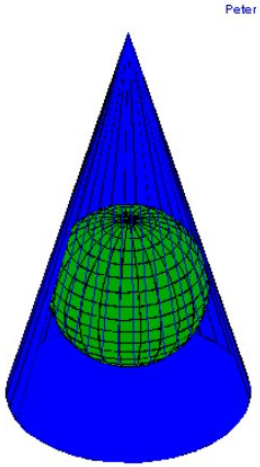
PLANAR (AZIMUTHAL) GRATICULE



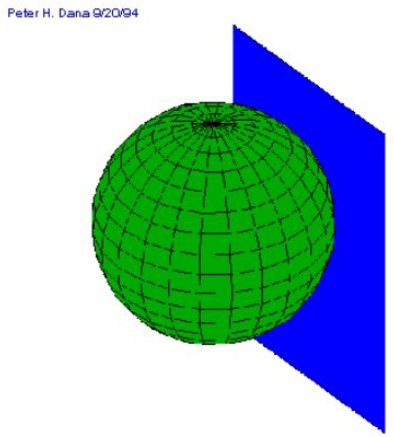
Tangent Projections



Cylindrical Projection Surface



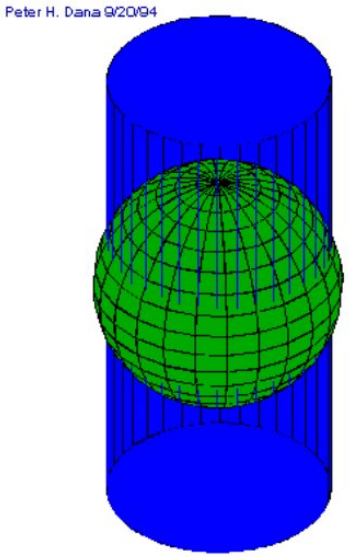
Conical Projection Surface



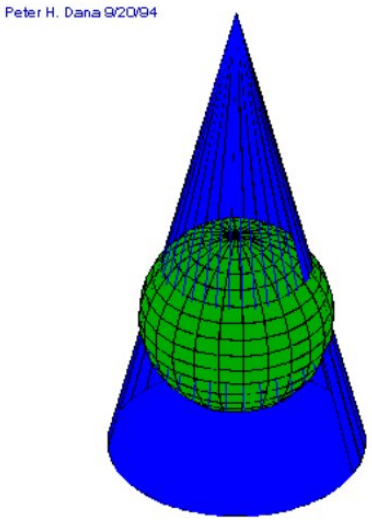
Planar Projection Surface

•Tangent projections have a **single standard point** (in the case of planar projection surfaces) or a **standard line** (for conical and cylindrical projection surfaces) of contact between the developable surface and globe

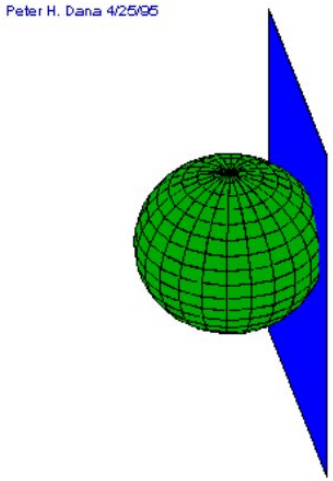
Secant Projections



Secant Cylindrical Projection



Secant Conic Projection

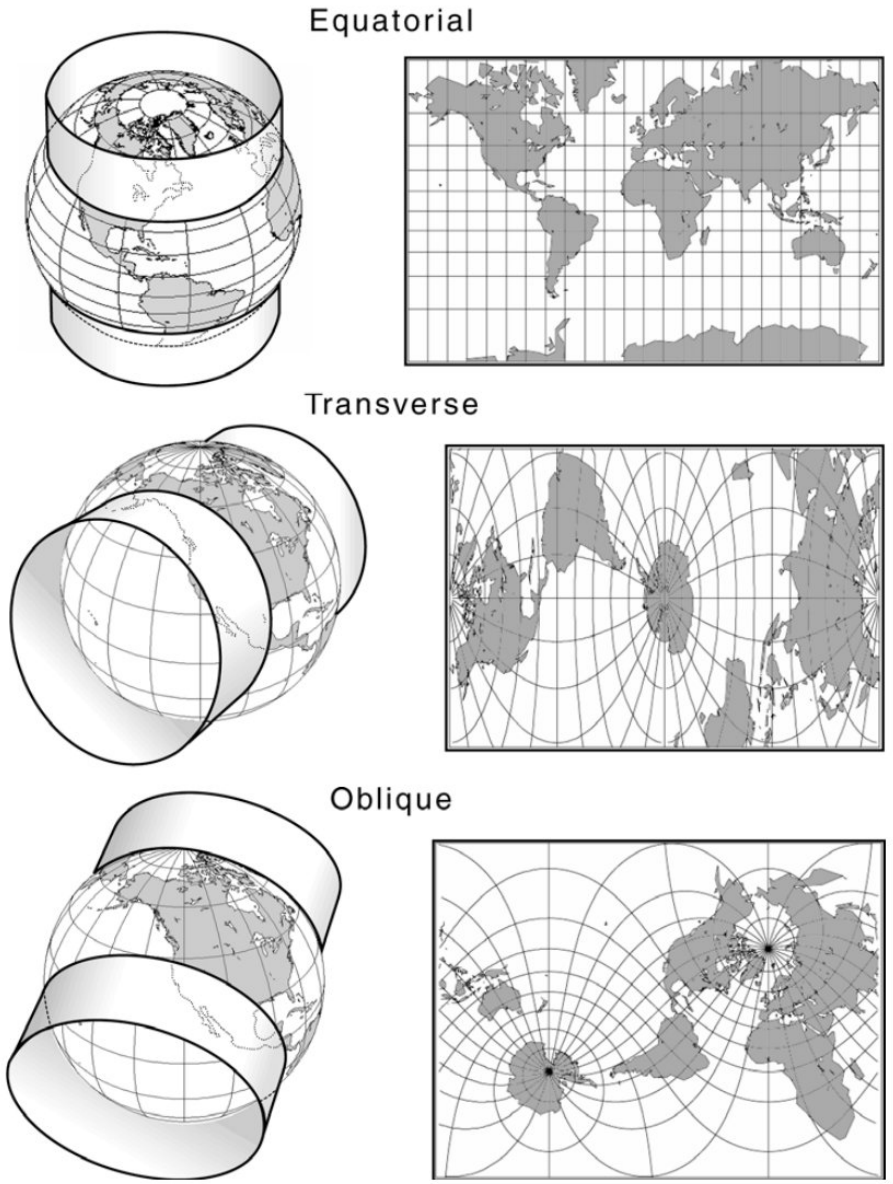


Secant Planar Projection

- Secant projections have a **single standard line** (in the case of planar projection surfaces) or **multiple standard lines** (for conical and cylindrical projection surfaces) of contact between the developable surface and the globe

Secant Map Projections

Figure 2.9
Variations on the Mercator (pseudocylindrical) projection shown as secant



Standard Parallels

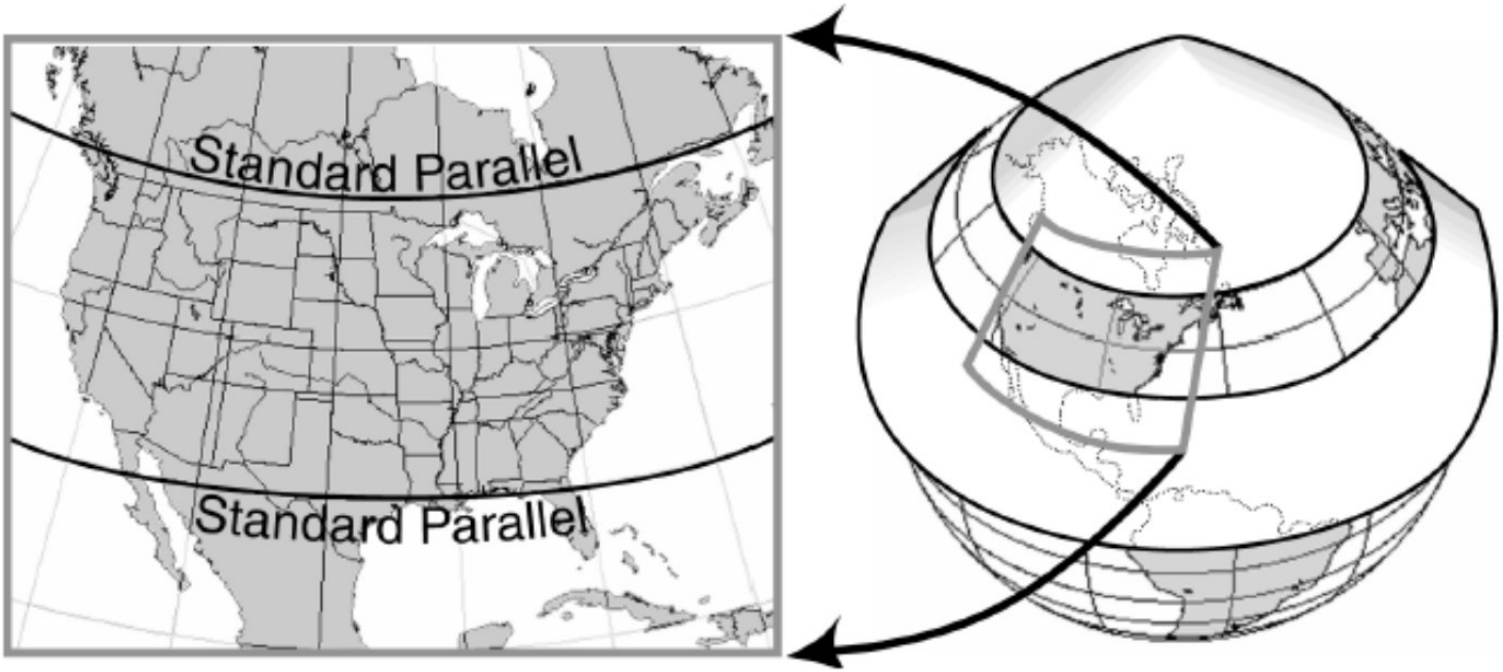


Figure 2.8 Standard parallels. The conic projection cuts through the globe, and the earth is projected both in and out onto it. This is a secant conic projection. Lines of true scale, where the cylinder and sphere touch, become standard parallels. If the touching is along one line, the projection is tangent and has one standard parallel.

Map Projections (continued)

- Projections can be based on axes **parallel** to the earth's rotation axis (equatorial), at **90 degrees to it** (transverse), or at **any other angle** (oblique).
- A projection that **preserves the shape** of features across the map is called **conformal**.
- A projection that **preserves the area** of a feature across the map is called **equal area or equivalent**.
- No flat map can be both equivalent and conformal. Most fall between the two as **compromises**.
- To **compare** maps in a GIS, both maps **MUST** be in the **same projection**.

No flat map can be both equivalent & conformal.

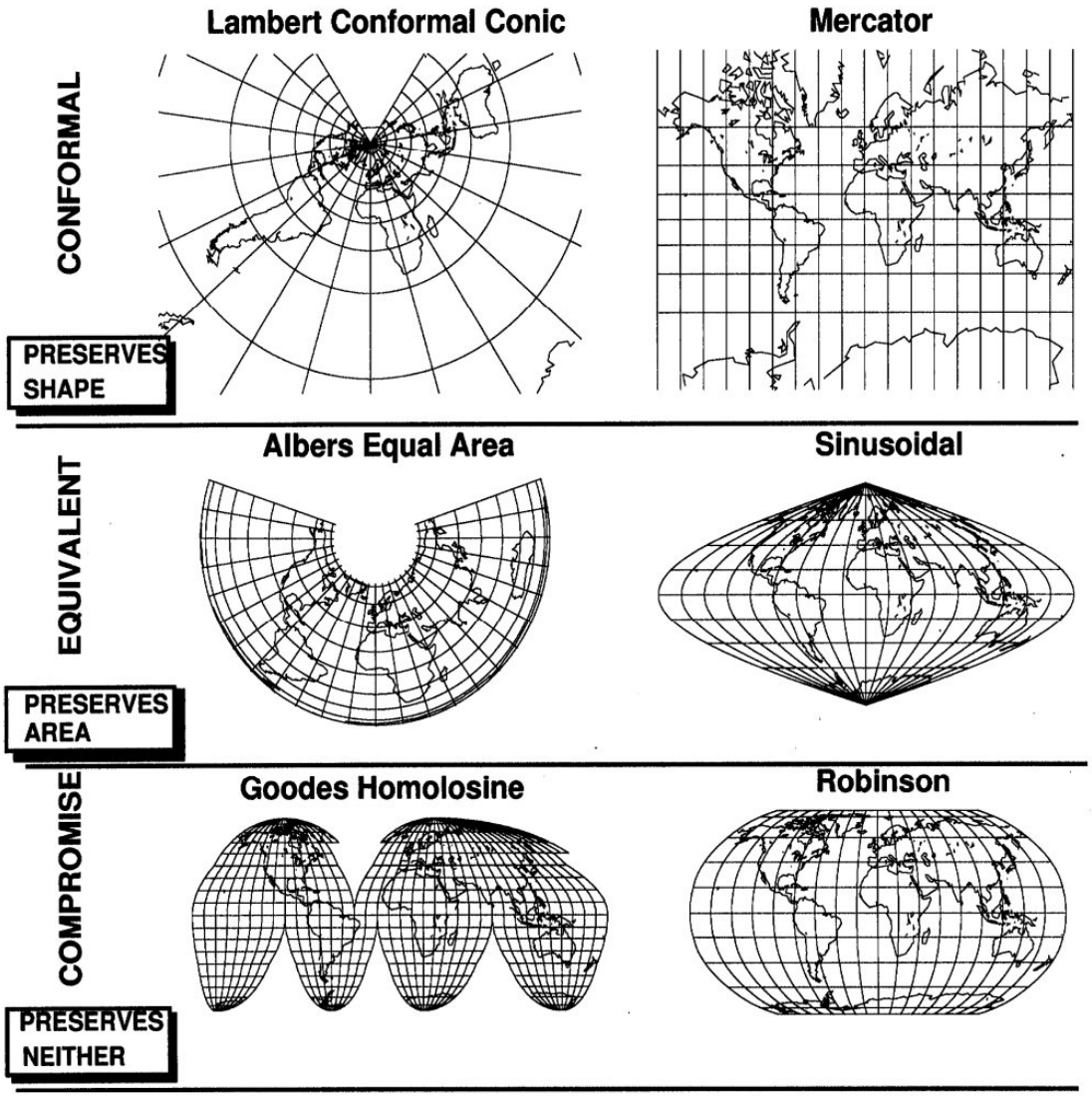


Figure 2.9 Examples of projections classified by their distortions. Conformal projections preserve local shape, equivalent projections preserve area, while compromise projections lie between the two. No projection can be equivalent and conformal.

Preservation of Properties

- Every map projection introduces some sort of **distortion** because there is always distortion when reducing our 3-dimensional reality to a 2-dimensional representation

- **Q:** How should we **choose** which projections to use?

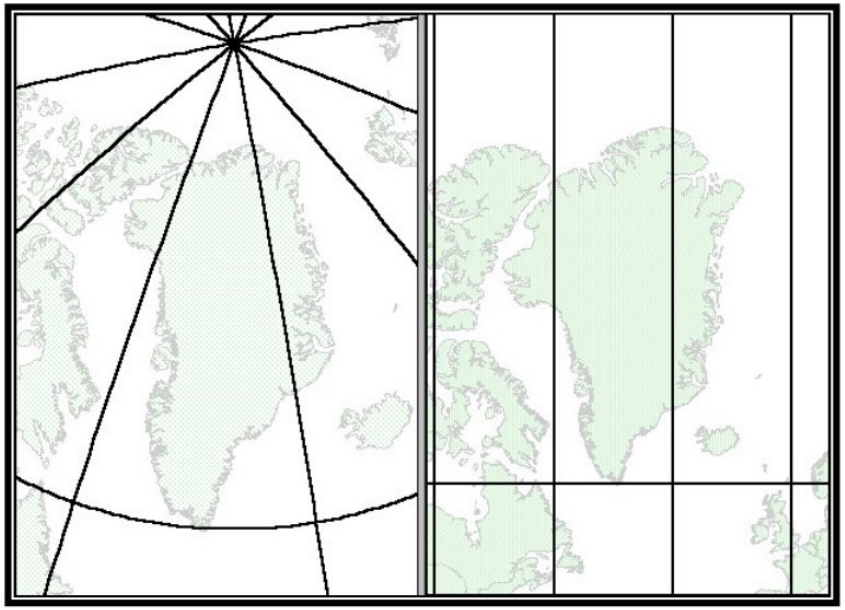
  A: We should choose a map projection that **preserves the properties** appropriate for the application, choosing from the following properties:

  1. Shape
  2. Area
  3. Distance
  4. Direction

Note: It may be more useful to classify map projections by the **properties they preserve**, rather than by the shape of their surfaces

Preservation of Properties - Shape

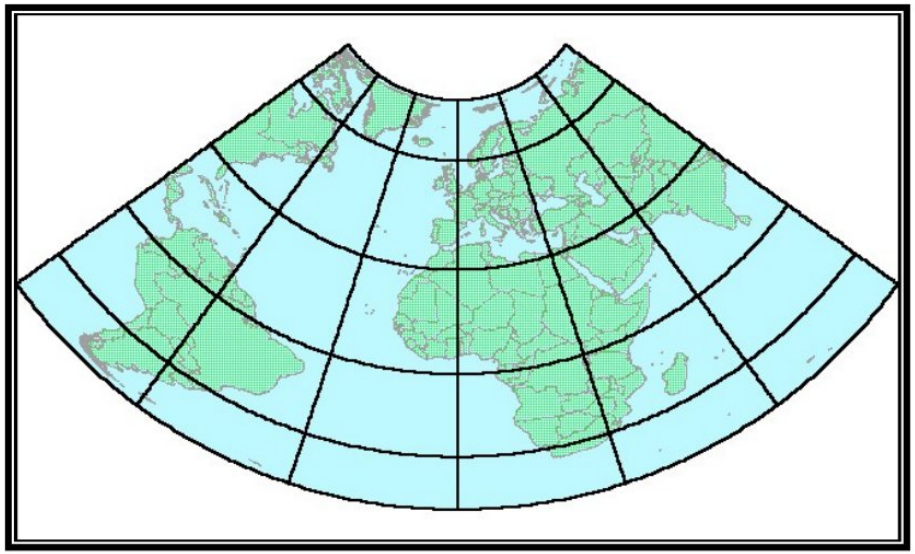
- If a projection preserves shape, it is known as a **conformal** projection
  - preserves **local shape** (i.e. angles of features)
  - graticule lines have **90°** intersection
  - **distortion** of shape, area **over longer distances**
  - **rhumb lines**
    - lines of constant direction



Greenland (Globe) Greenland (Mercator)

Preservation of Properties - Area

- **Equal Area Projections**
  - **preserve** the **area** of displayed features
  - however, shape, distance, direction, or any combination of these may be **distorted**
  - on large-scale maps, the distortion can be quite difficult to notice

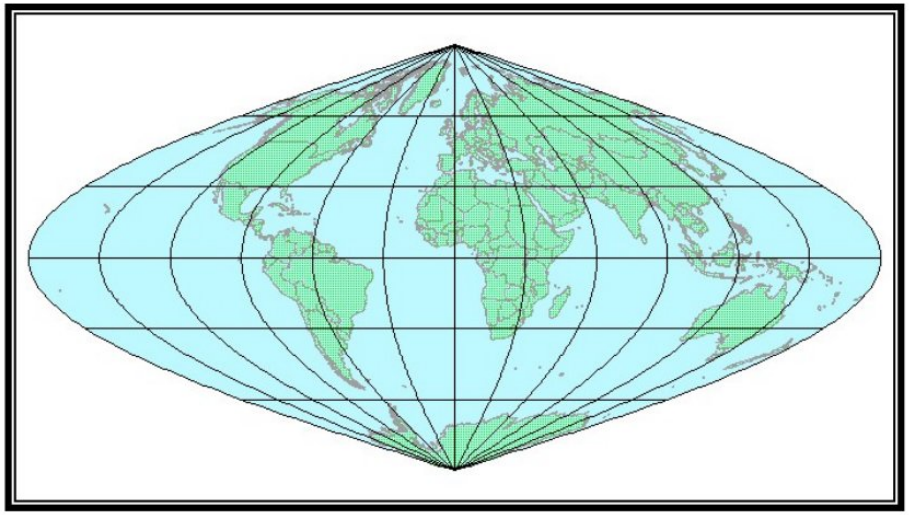


Albers Equal-Area Conic

A projection **cannot preserve both** shape and area!

Preservation Properties - Distance

- **Equidistant Projections**
  - **preserve** the **distance** between certain points
  - they maintain scale along one or more lines
  - display true distances

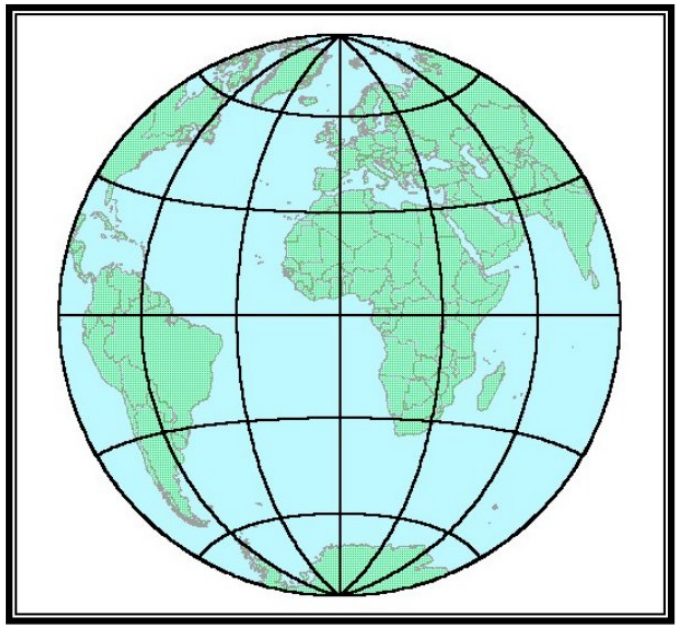


Sinusoidal

A projection **cannot preserve distance** everywhere!

Preservation Properties - Direction

- **Azimuthal Projections**
  - preserve **directions**, or azimuths, of all points on the map with respect to the center
  - They can also be
    - conformal
    - equal-area
    - equidistant



Lambert Equal-Area Azimuthal

A projection **cannot preserve direction** everywhere!