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

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 more global characteristics:
  - Shape
  - Area
  - Distance
  - Direction
  - Position

Characteristics of a Globe 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

- 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
**Equivalent or Equal Area Projections**

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- 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**

```
  Pole
    |   |   |
  0°   20°  0°
  a   b   d
  c
  e
```

**Mollweide Equivalent Projection**

**Equivalent & Conformal**

- **Preserve true shapes and exaggerate areas**
  - OR **Show true size and squish/stretch shapes**

**Equidistant Projections**

- **Length of a straight line between two points represents correct great circle distance.**
  - OR **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.

\[ \theta \]
\[ \theta = \text{Azimuth of green line} \]

Plane Projection: Lambert Azimuthal Equal Area

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.

Planar Projection Surface
**Plane Projection**
- Equidistant
- Azimuthal

**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.

**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.
“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*.
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

Transverse Orientation

Oblique Orientation

Putting Things Together

Mercator Projection

Cylindrical Projection Surface

Transverse Cylindrical Projection Surface

Varieties of geometric projections

Projection Orientation or Aspect
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

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.
**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.

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.

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
Robinson Projection
Mollweide Equivalent Projection
Sinusoidal Equal Area Projection
Briemeister
Fuller Projection

Projections & Coordinate Systems for Large Scale Mapping