Map Projections

Displaying the earth on 2 dimensional maps

Map projections …

- Define the spatial relationship between locations on earth and their relative locations on a flat map
- Are mathematical expressions which transform the spherical earth to a flat map
- Cause the distortion of one or more map properties (scale, distance, direction, shape)

Map projections …

- Are easy if you let software calculate the numbers for you
- Otherwise map projections look like this …

```
lat = lat * DR;       /* set to radians */
lon = lon * DR;
lono = lono * DR;
partA = tan(DR*(180.0/4) - lat/2.0);
partB = pow(((1-e*sin(lat))/(1+e*sin(lat))),e/2);
t = partA / partB;
m = cos(c)/sqrt(1 - (e*e) * sin(c));
partA = tan(DR*(180.0/4) - c/2.0);
partB = pow(((1-e*sin(c))/(1+e*sin(c))),e/2);
tc = partA / partB;
p = a * m * (t / tc);
*x =  p * sin(lono - lon);
*x =  *x * -1.0; /* reverse signs for southern hemisphere */
*y =  (p * cos(lono - lon)) * -1.0;
*y =  *y * -1.0;
```

Classifications of Map Projections

Conformal – local shapes are preserved

Equal-Area – areas are preserved

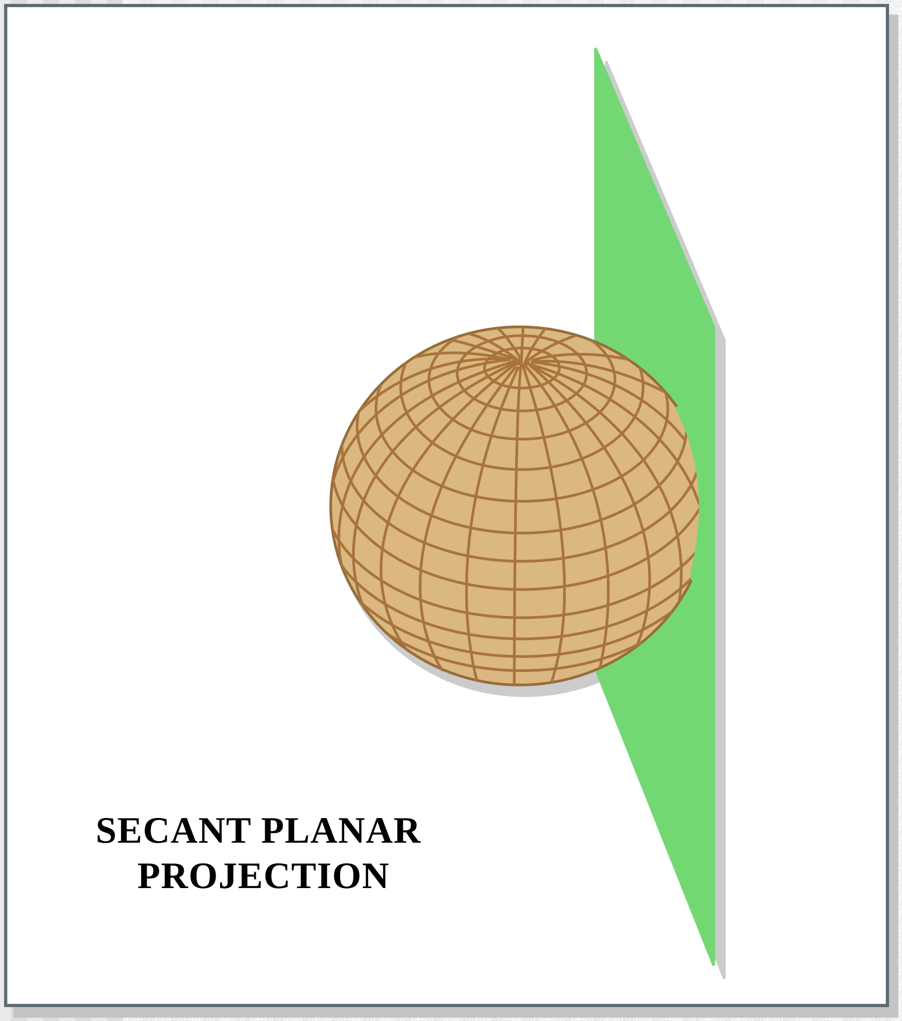
Equidistant – distance from a single location to all other locations are preserved

Azimuthal – directions from a single location to all other locations are preserved

Another classification system

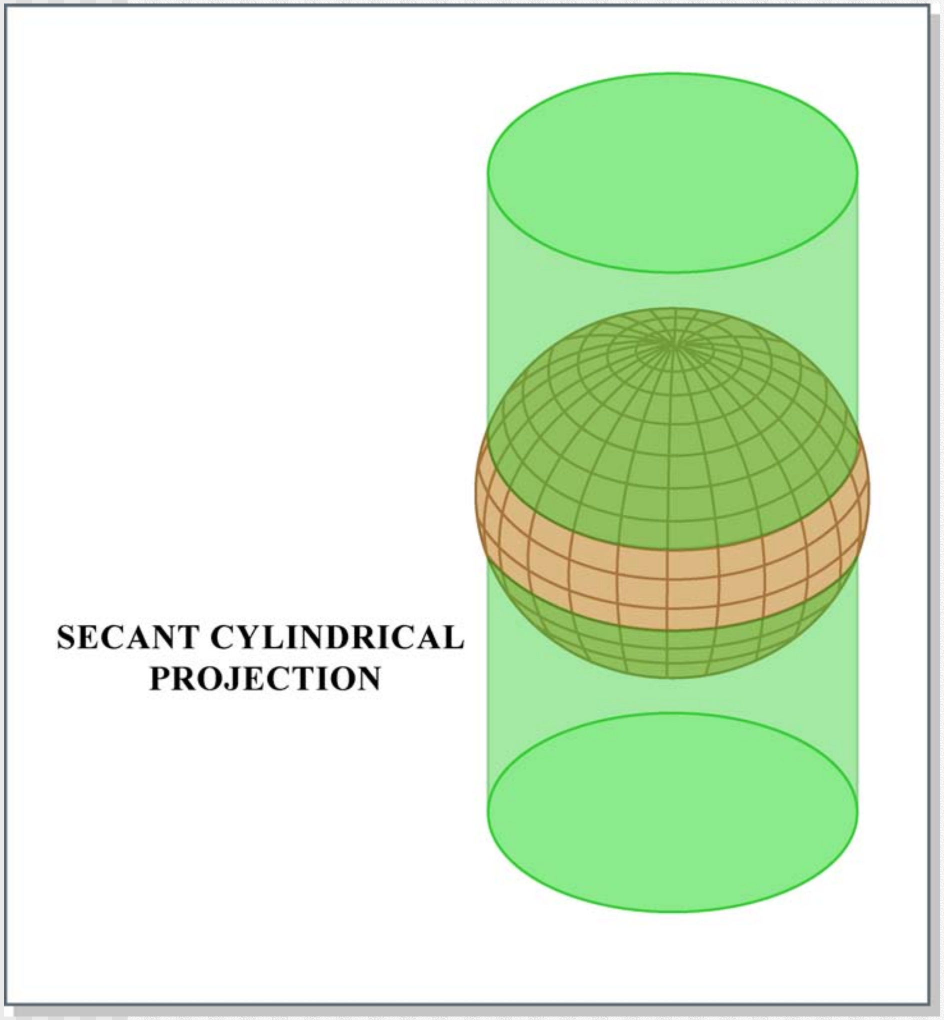
- By the geometric surface that the sphere is projected on
  - Planar
  - Cylindrical
  - Conic

Planar surface



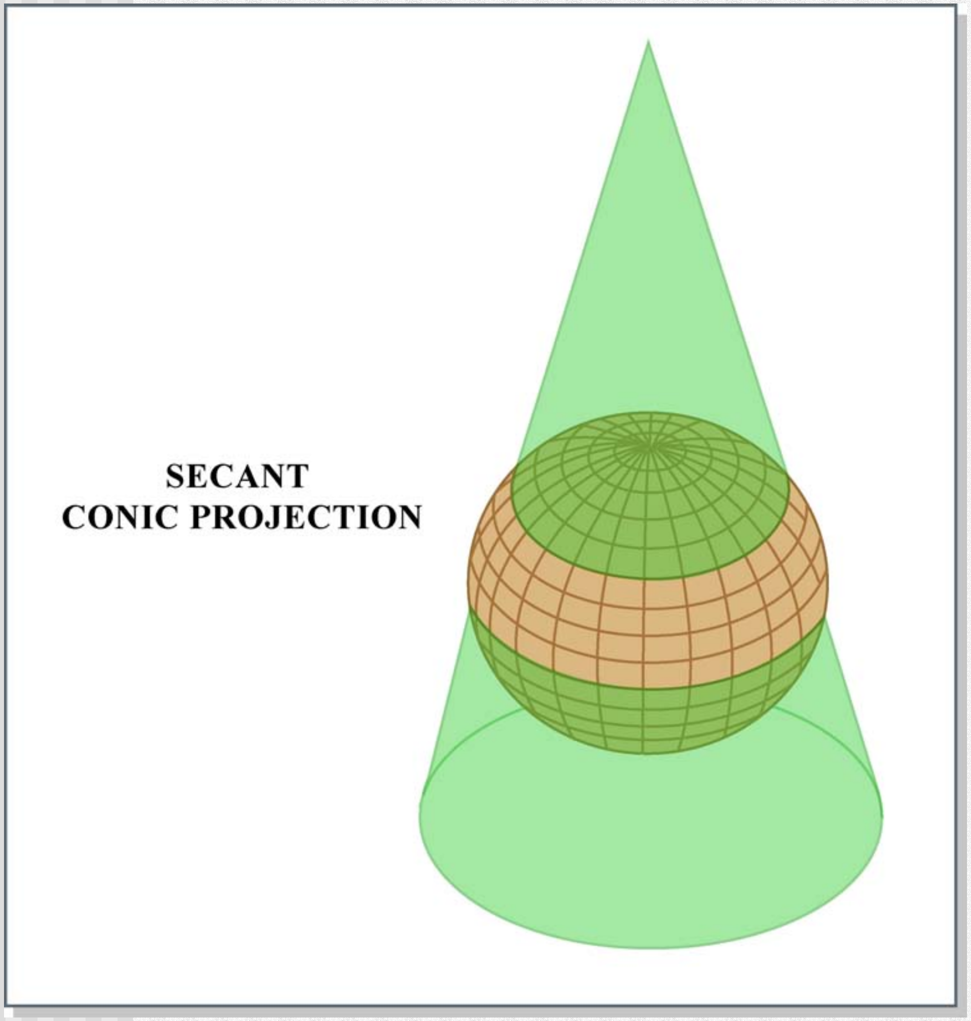
Earth intersects the plane on a small circle. All points on circle have no scale distortion.

Cylindrical surface



Earth intersects the cylinder on two small circles. All points along both circles have no scale distortion.

Conic surface



Earth intersects the cone at two circles. all points along both circles have no scale distortion.

Scale distortion

- Scale near intersections with surface are accurate
- Scale between intersections is too small
- Scale outside of intersections is too large and gets excessively large the further one goes beyond the intersections

Size of map influences on scale distortions

- The small the scale (a larger displayed area), the greater the distortion
- The larger the scale (a small displayed) area, the smaller the distortion – for very small areas, the earth can be considered a plane.

Why project data?

- Data often comes in geographic, or spherical coordinates (latitude and longitude) and can’t be used for area calculations
- Some projections work better for different parts of the globe giving more accurate calculations

Projection parameters

- Units – the unit of measure used for map coordinates and calculations in a GIS – typically meters or feet
- Scale – map scale (because of distortion, this is not a constant throughout the data set).

More parameters

- Standard parallels and meridians – the place where the projected surface intersects the earth – there is no scale distortion
- Central meridian – on conic projects, the center of the map (balances the projection, visually)

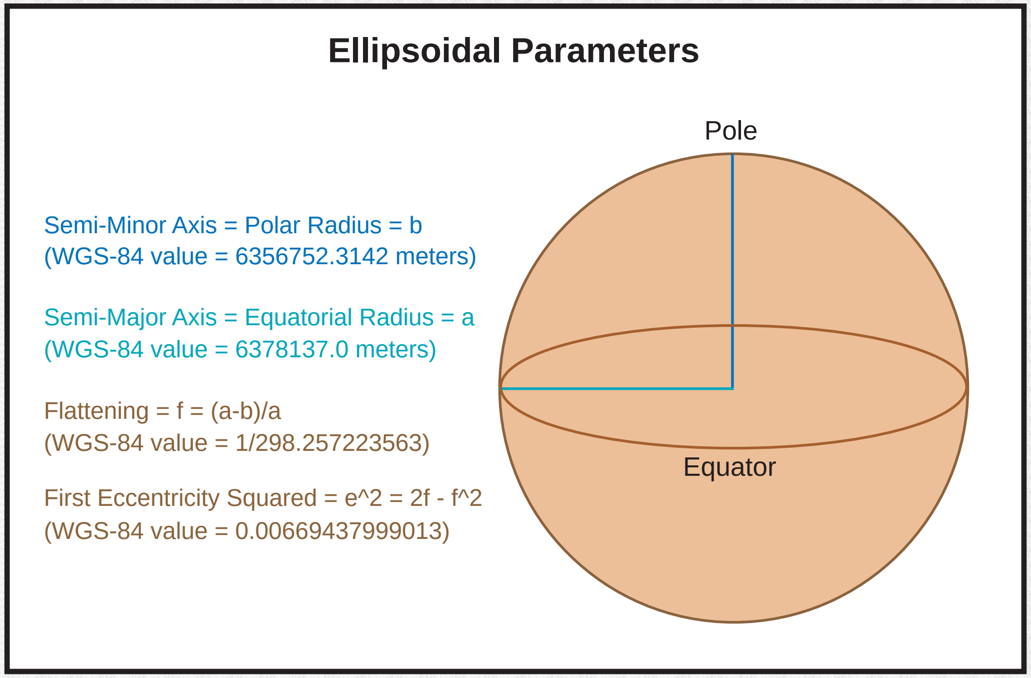
More parameters

- Ellipsoid – the best fit ellipsoid that matches the shape of the earth
- Datum – system for fitting the ellipsoid to known locations. There is local and global datums. NAD27 and NAD83 are most common in the United States

Datums

- Define the shape of the earth including:
  - Ellipsoid (size and shape)
  - Origin
  - Orientation
    - Aligns the ellipsoid so that it fits best in the region you are working

Ellipsoid parameters



More parameters

- Scale factor – the ratio between the actual scale and the scale represented on the map (often between standard parallels
- Map origin – where map coordinates are 0, 0
- Easting, Northings – constant added to coordinates so all values are > 0

How to choose projections

- Generally, follow the lead of people who make maps of the area you are interested in. Look at maps!
- State plane is a common projection for all states in the USA
- UTM is commonly used and is a good choice when the east-west width of area does not cross zone boundaries

Standard parallel – 1/6 rule and the Albers Equal Area

- Conic projection
- Divide the north-south extent of the area you are showing into 6ths. The 1st standard parallel is one 6th from the bottom of the area and the 2nd is 1/6 from the top.
- Minimizes distortion between and outside of the standard parallels

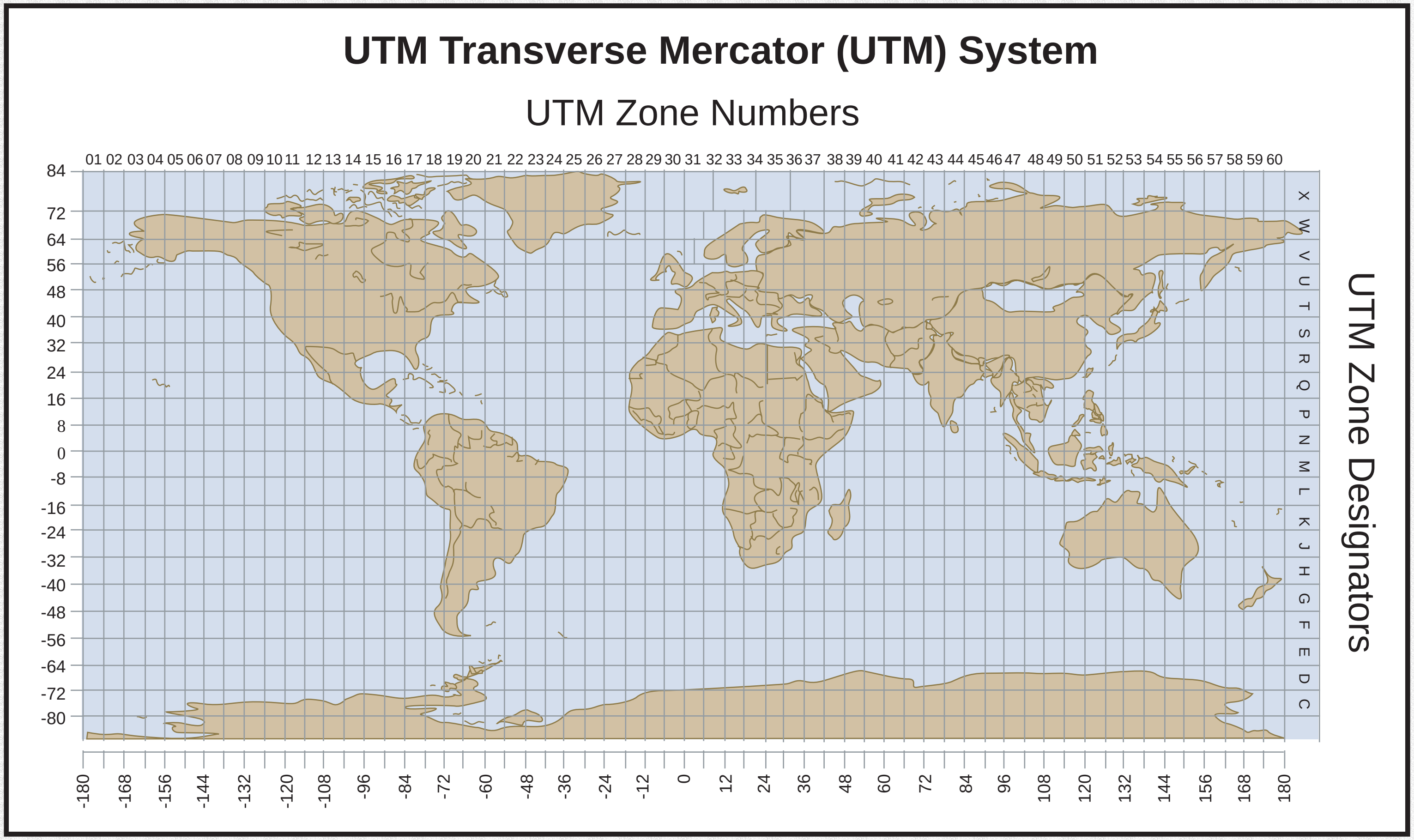
UTM projection

- Universe Transverse Mercator
- Conformal projection (shapes are preserved)
- Cylindrical surface
- Two standard meridians
- Zones are 6 degrees of longitude wide

UTM projection

- Scale distortion is 0.9996 along the central meridian of a zone
- There is no scale distortion along the the standard meridians
- Scale distortion is 1.00158 at the edge of the zone at the equator (1.6 meters in 1000 meters)
- Scale distortion gets to unacceptable levels beyond the edges of the zones

UTM zones


UTM Transverse Mercator (UTM) System
UTM Zone Numbers
01 02 03 04 05 06 07 08 09 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
-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
UTM Zone Designators

State Plane Coordinate System

- System of map projections designed for the US
- It is a coordinate system vs a map projection (such as UTM, which is a set of map projections)
- Designed to minimize distortions to 1 in 10000

More State Plane

- States are divided into 1 or more zones – Massachusetts is made up of two zones
- Common projections systems
  - Transverse Mercator
  - Lambert Conformal Conic

Projecting Grids from spherical coordinates

- Cells are square in a raster GIS but:
  - Size of cell changes with latitude – for example, 1 minute (of arc) 1854 meters by 1700 meters in Florida and 1854 meters by 1200 meters in Montana.
- Problems:
  - Impossible to match cells one to one in two different projections – resampling or nearest neighbor

Projecting grids

- Projected cells require weighted average resampling vs nearest neighbor (reserved for categorized data)
- Forward and reverse projections of grids are not exact
- Optimal size of cell should be the minimum dimension so no data is lost.