Map projections and distortions

VIS 2129

Map projection resources

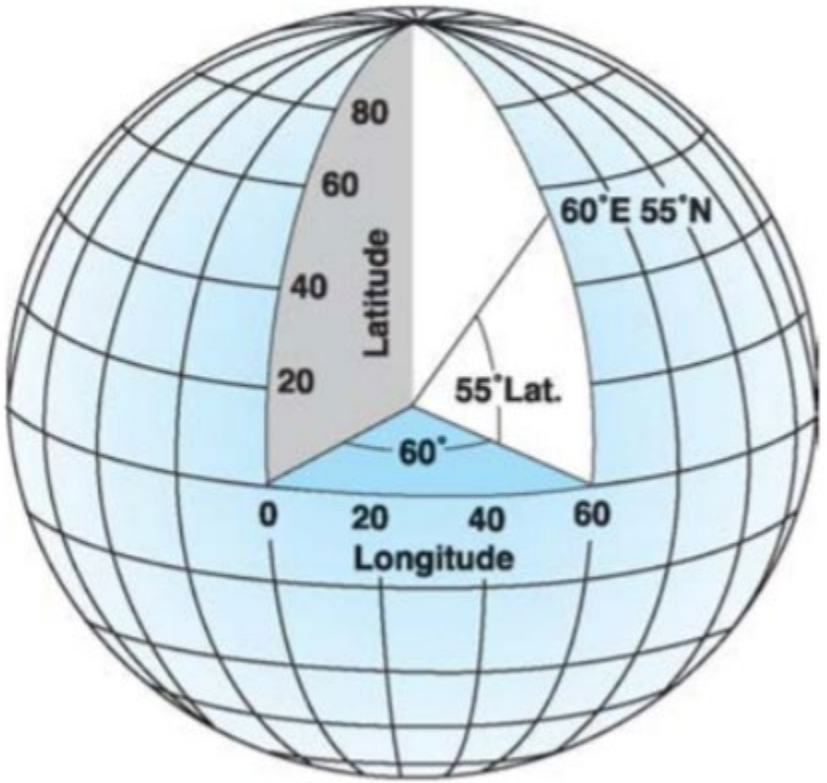
- *Understanding Map Projections* (ESRI 2000)
- PROJ documentation (especially https://proj.org/usage/projections.html)
- spatialreference.org

https://www.youtube.com/watch?v=vVX-PrBRtTY

All models are wrong, but some are useful.

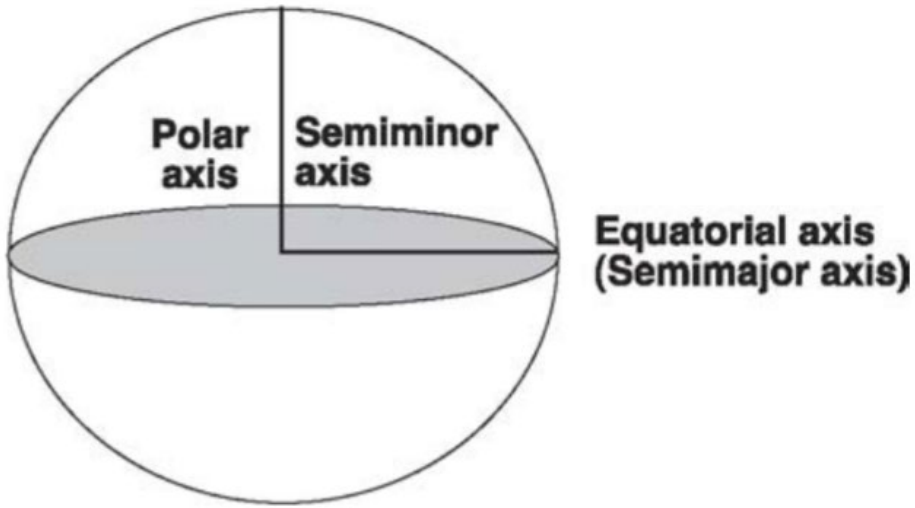
- George Box

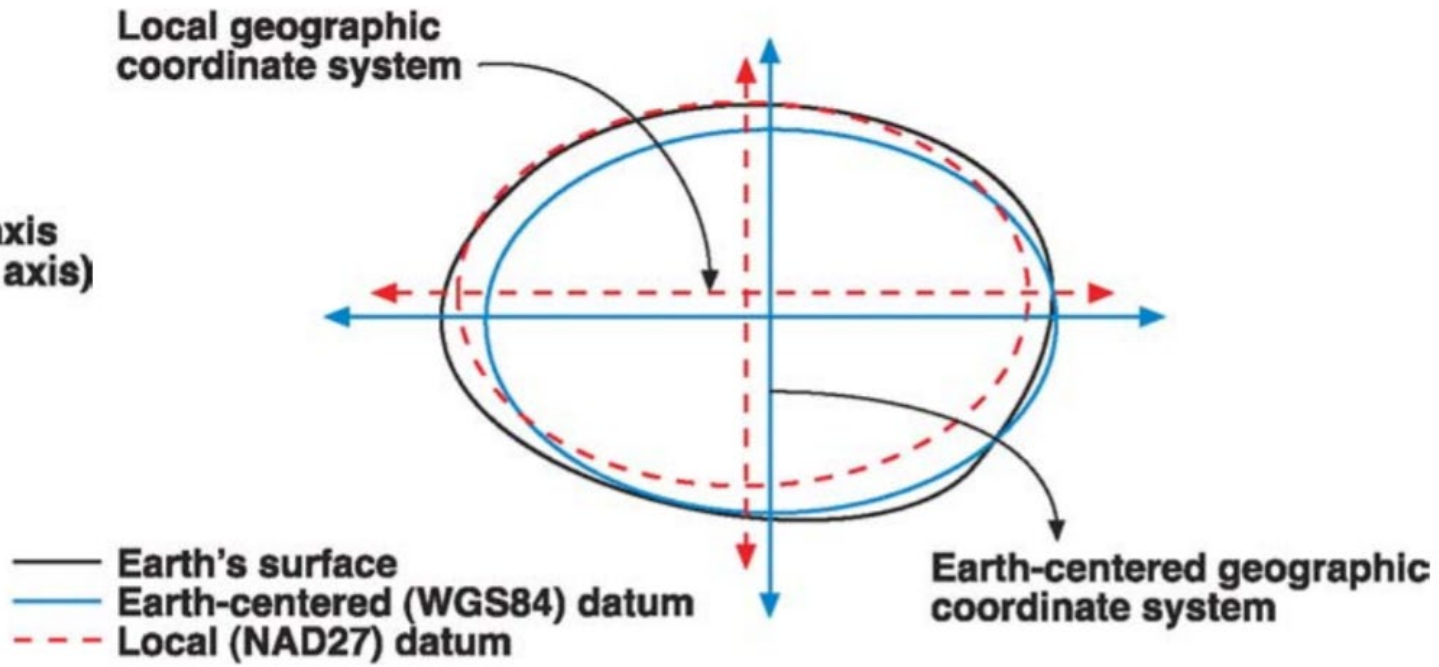
Geographic Coordinate Systems



The earth is not a perfect sphere…

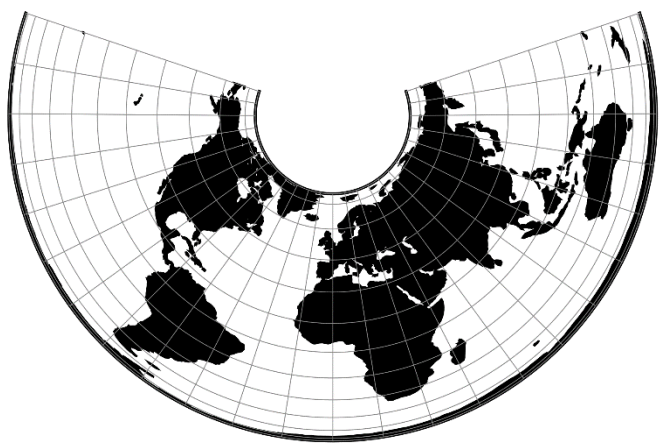
It isn’t even symmetrical.

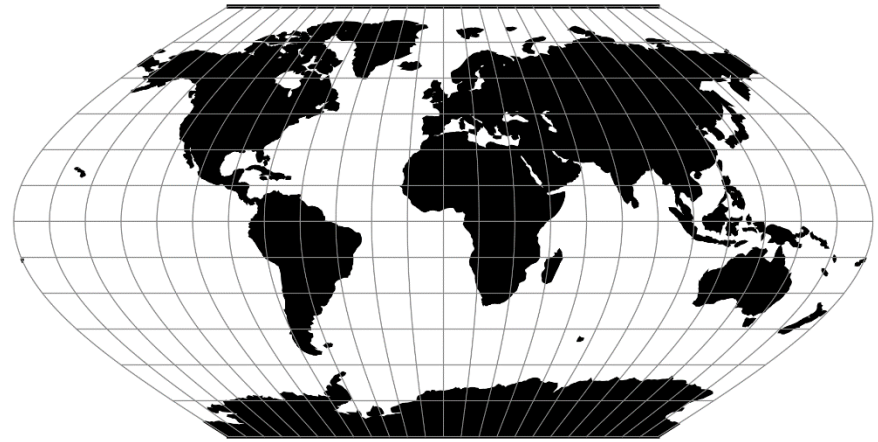


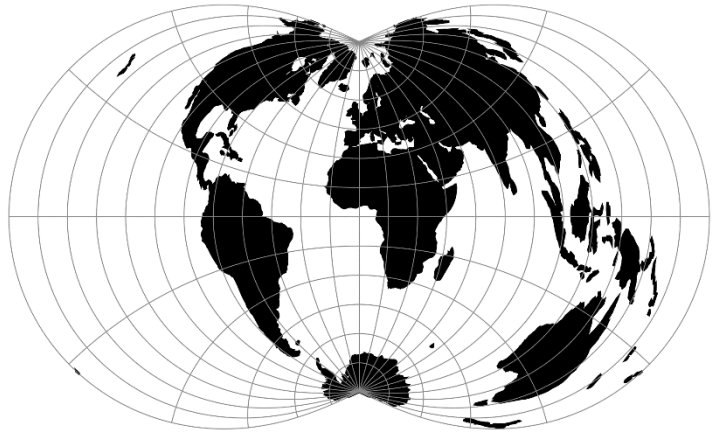


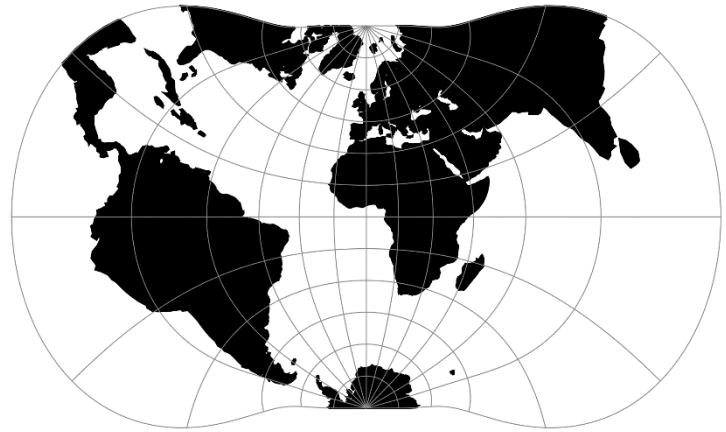
Questions?

Projected coordinate systems



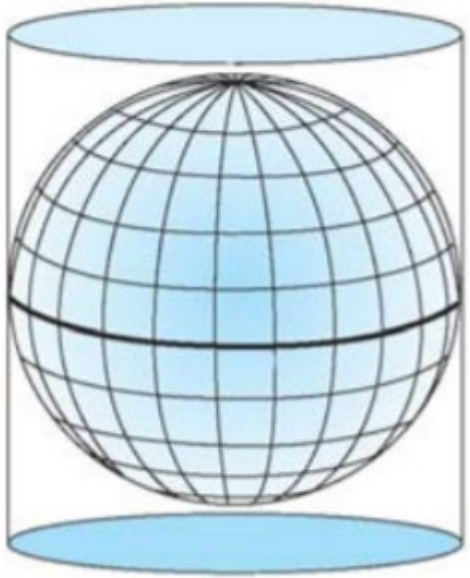




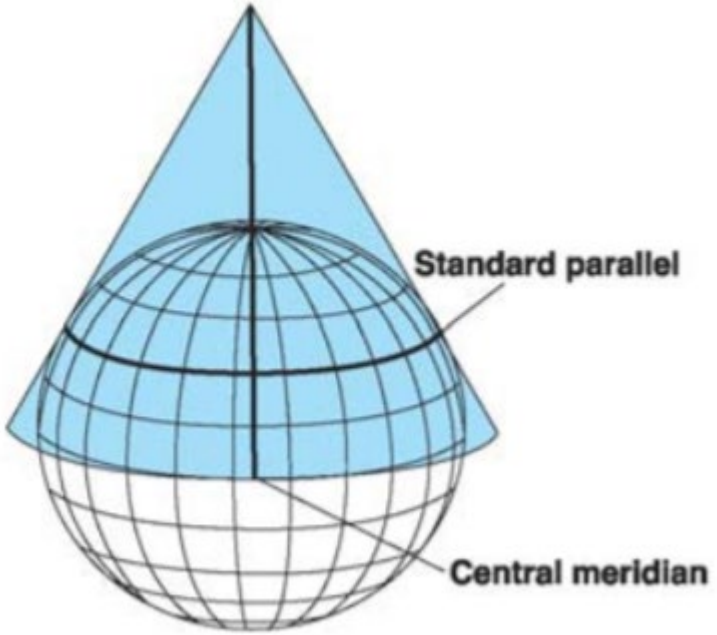


Basic types of projections

Planar



Cylindrical

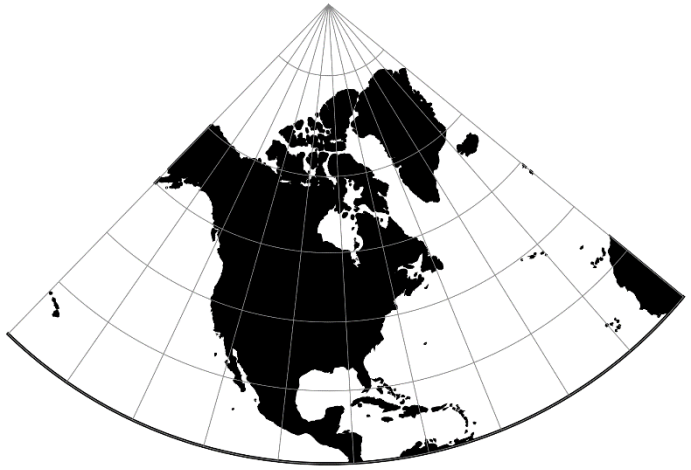


Conic

Distortions in projected coordinate systems

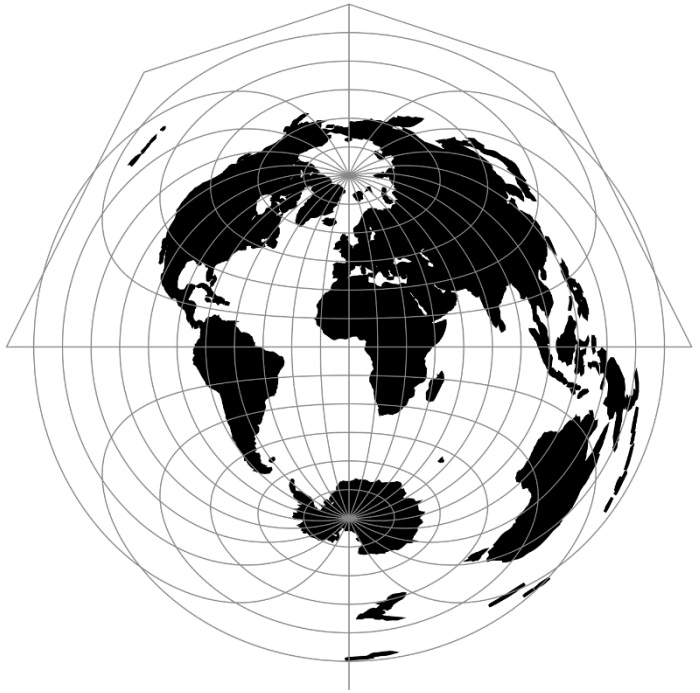
Area (Equal area projections)

Shape (Conformal projections)



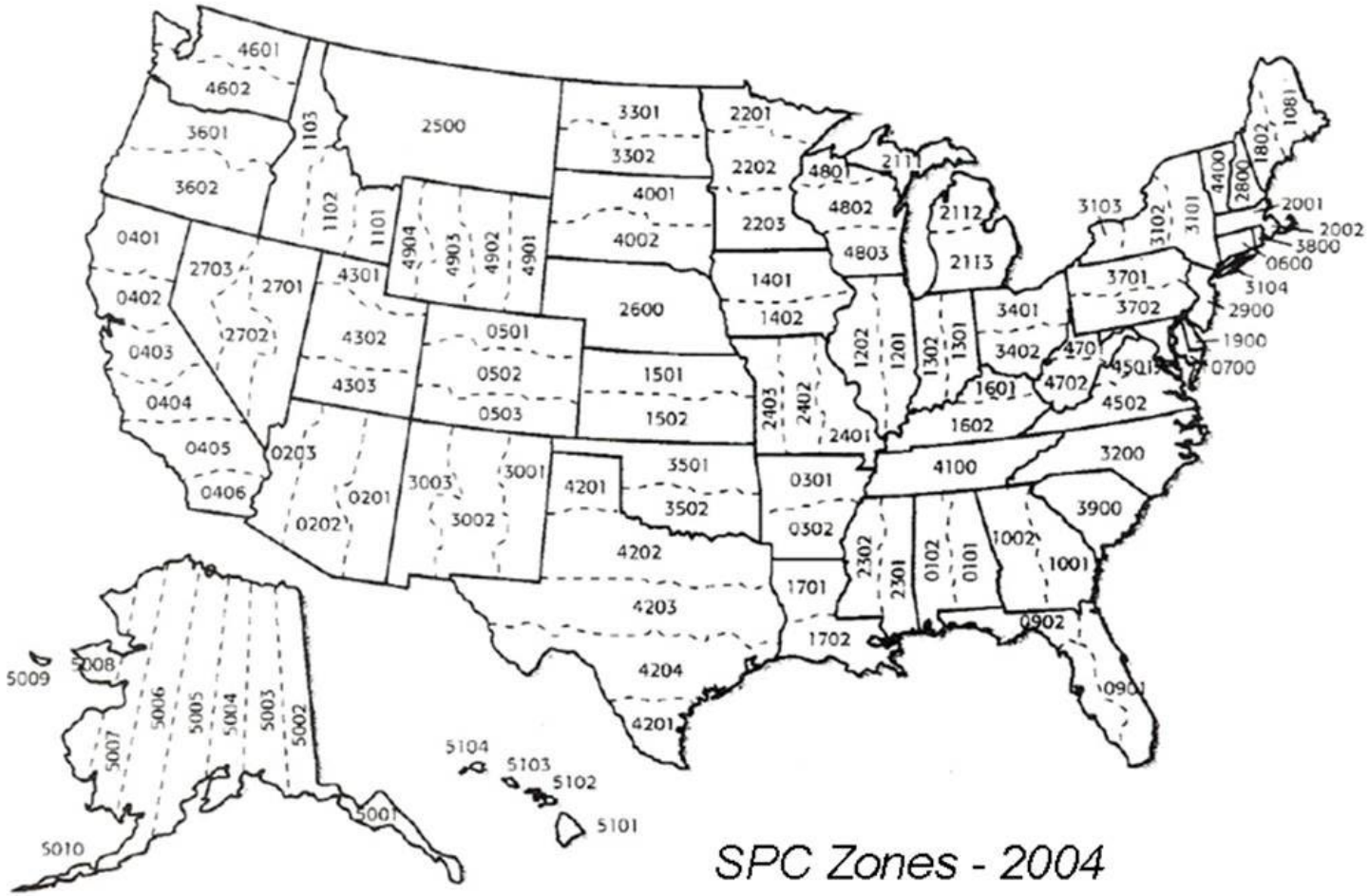
Direction (True-direction projections)

Distance (Equidistant projections)



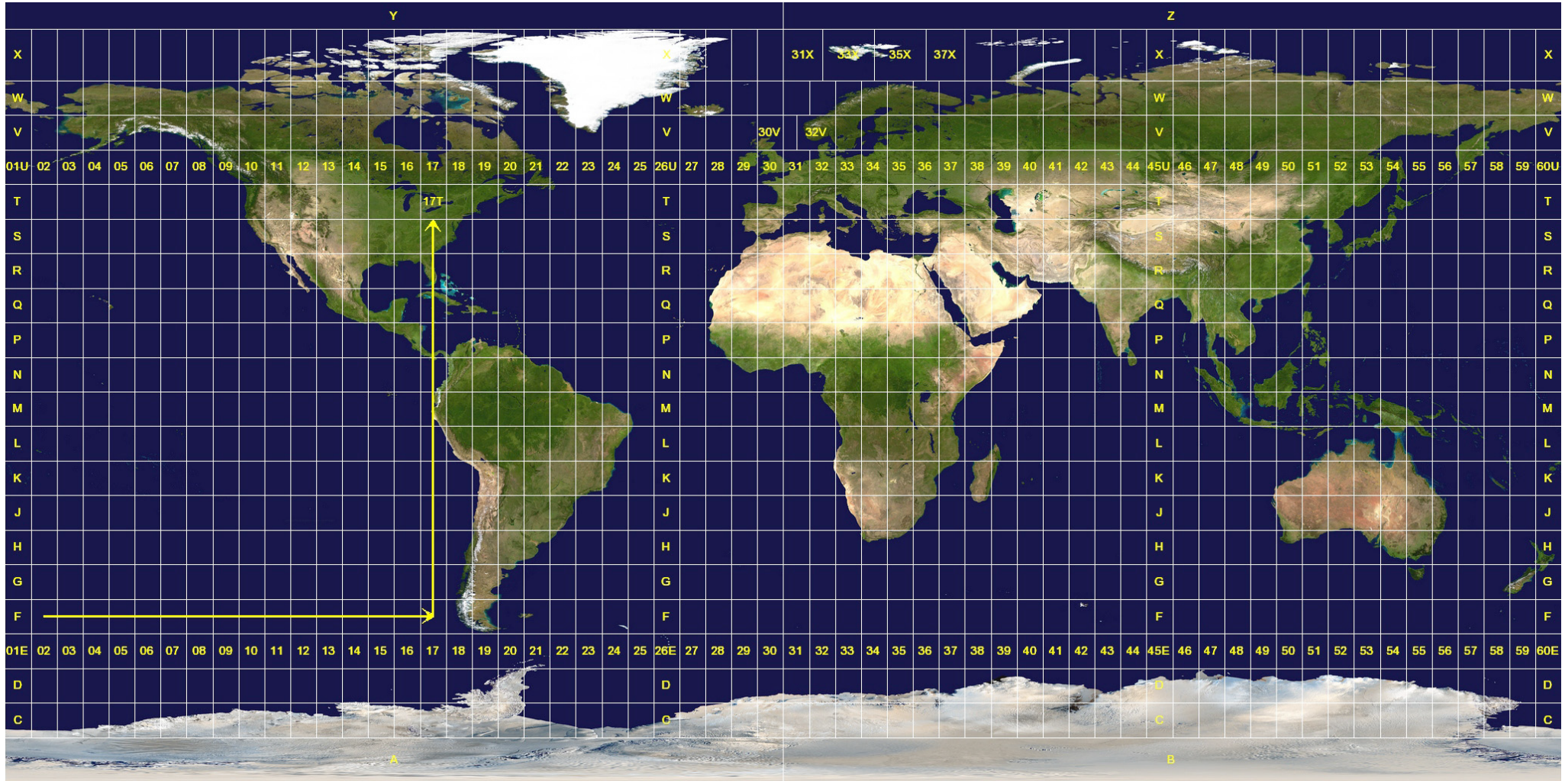
Questions?

State Plane Coordinate systems



Usually **Lambert Conformal Conic** (for long east-west zones) or **Transverse Mercator** (for long north-south zones)

Universal Transverse Mercator (UTM)



Questions?

If your goal is to create a useful map, consider:

For maps with each of the uses listed on the right, what (if anything):

- Should you distort?
- Can you distort?
- Should you show as accurately as possible?

- *Distance?*
- *Direction?*
- *Area?*
- *Shape?*
- *Something else?*

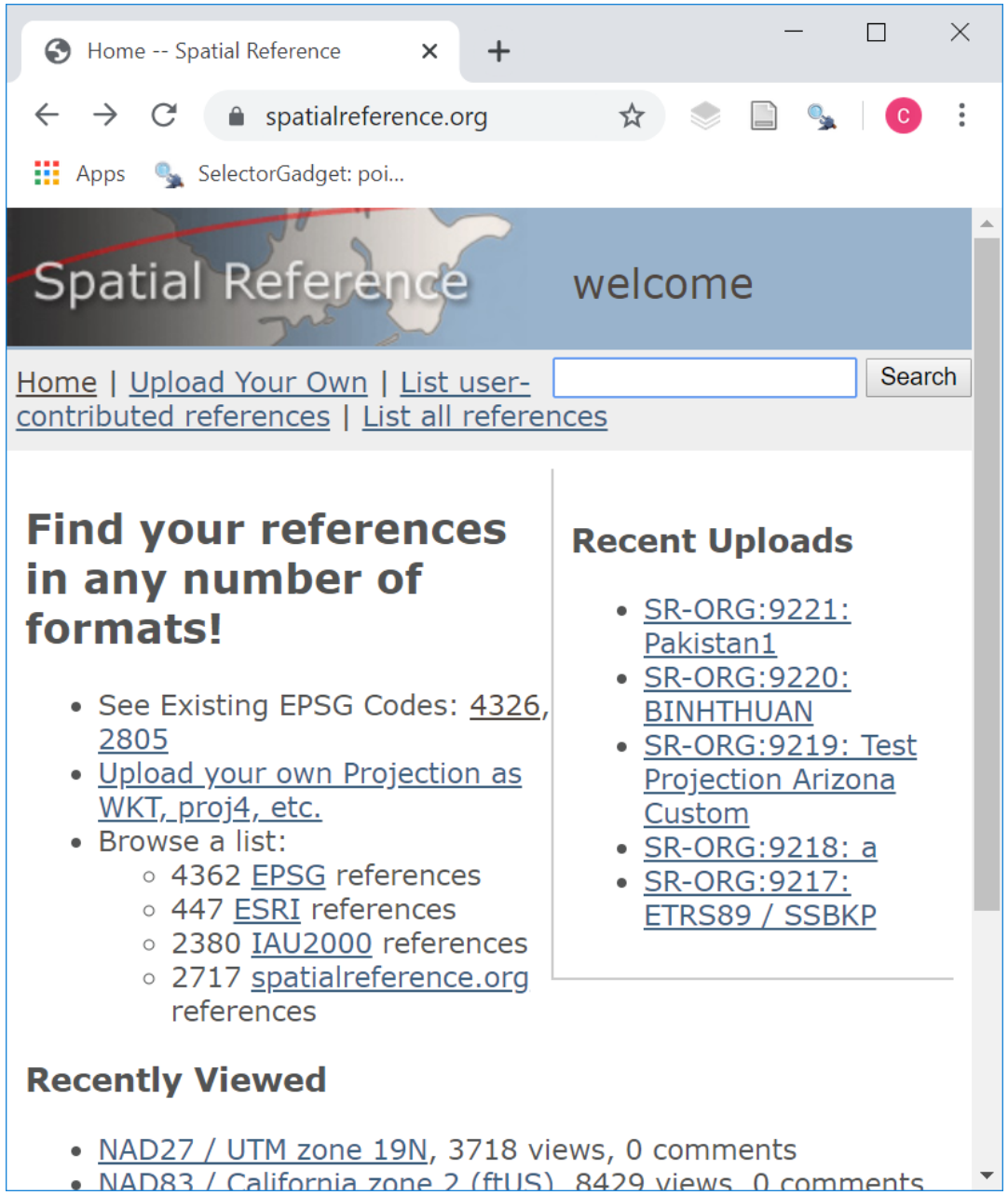
A map showing

- Election results by state
- Lines on a subway transit system
- Bicycle routes
- Navigation routes across the ocean
- Walking routes (posted to a sign/kiosk)
- Areas of a coastal state that are vulnerable to sea-level rise

The rest of this mostly applies to those working in R…

Recommendation

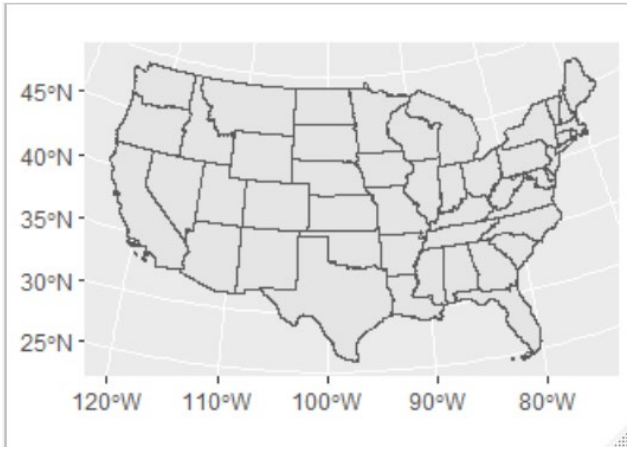
- Search for the appropriate coordinate reference system on spatialreference.org

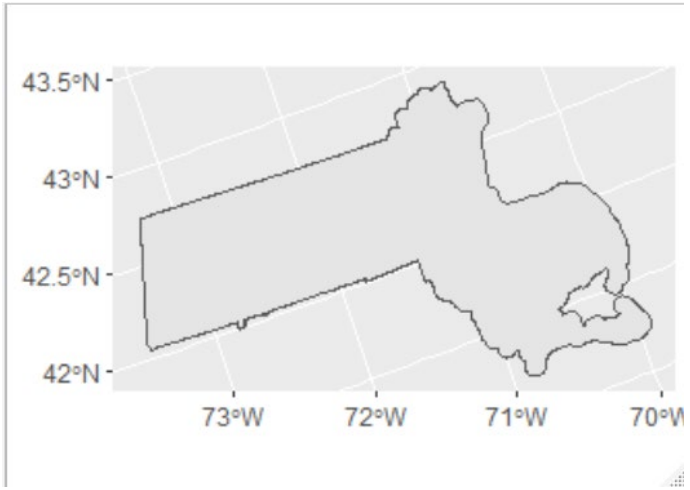


Projections in R (PROJ notation)

```
states48 %>%
 st_transform(
    "+proj=laea +lat_0=45 +lon_0=-100 +a=6370997 +b=6370997 +no_defs") %>%
  ggplot() +
  geom_sf()

MA %>%
  st_transform(
    "+proj=laea +lat_0=45 +lon_0=-100 +a=6370997 +b=6370997 +no_defs") %>%
  ggplot() +
  geom_sf()
```

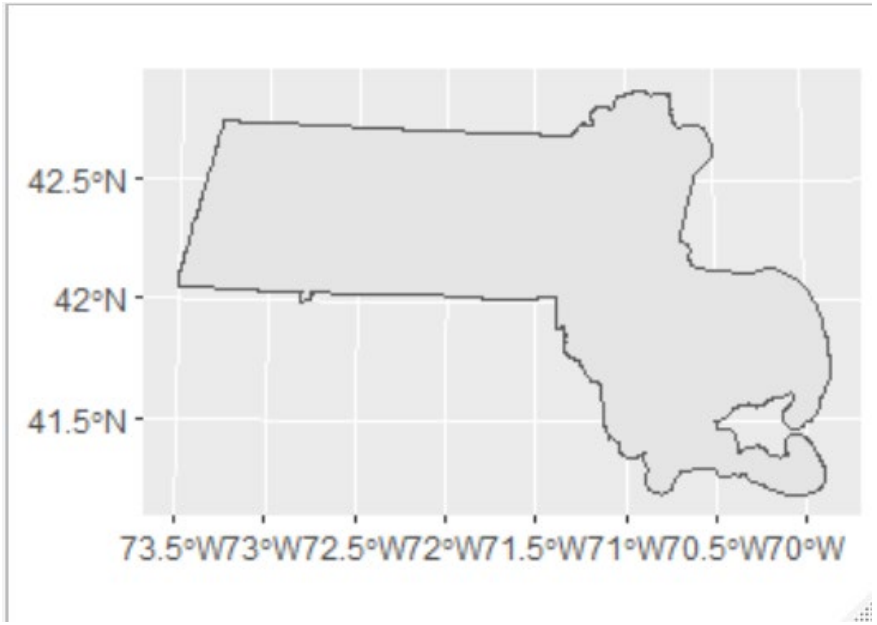


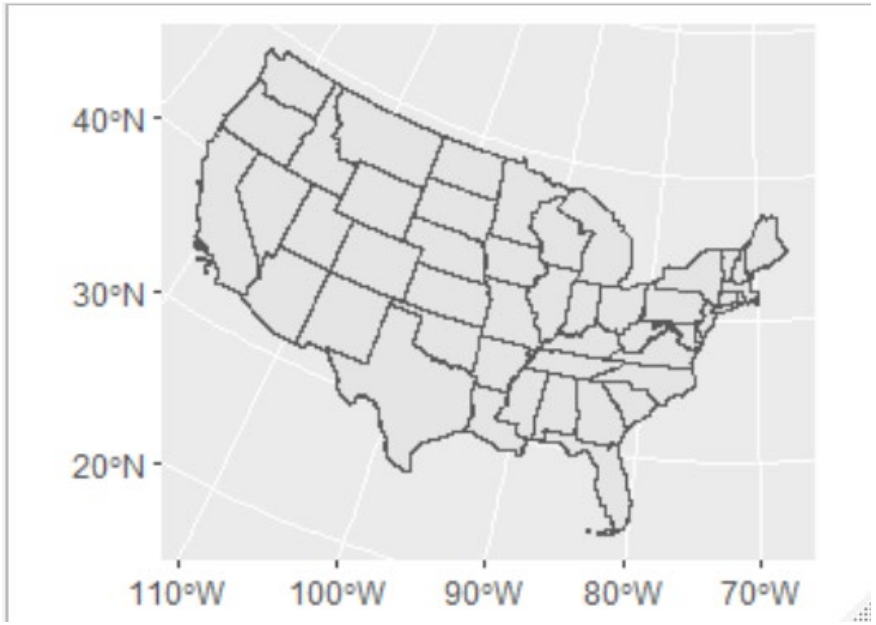


Projections in R (PROJ notation)

```
MA %>%
  st_transform(
    " +proj=lcc +lat_1=42.6833 +lat_2=41.7167 +lat_0=41 +lon_0=-71.5 +x_0=200000 +y_0=750000 +units=m +ellps=GRS80 +datum=NAD83 +no_defs ") %>%
  ggplot() +
  geom_sf()

states48 %>%
 st_transform(
    " +proj=lcc +lat_1=42.6833 +lat_2=41.7167 +lat_0=41 +lon_0=-71.5 +x_0=200000 +y_0=750000 +units=m +ellps=GRS80 +datum=NAD83 +no_defs ") %>%
  ggplot() +
  geom_sf()
```





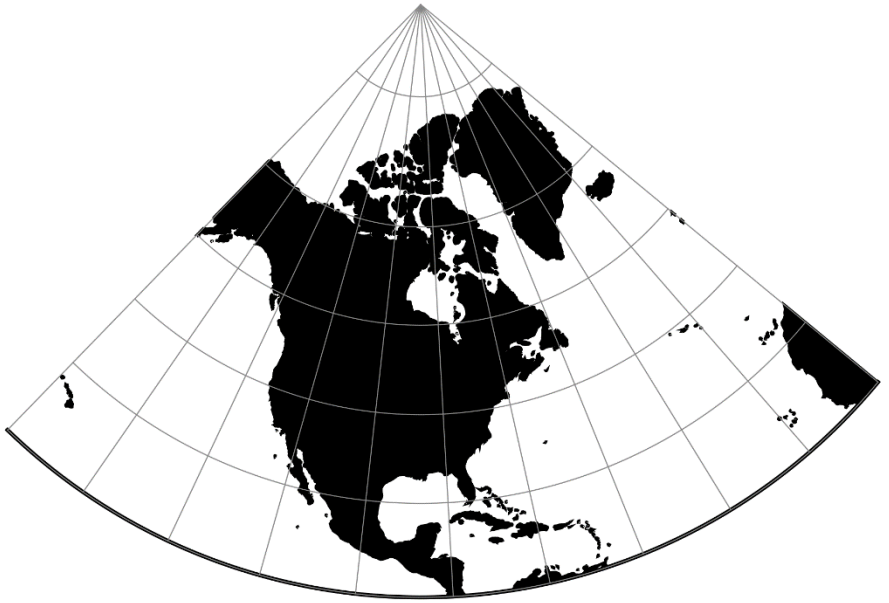
```
+proj=lcc +lat_1=42.6833 +lat_2=41.7167 +lat_0=41 +lon_0=-71.5 +x_0=200000 +y_0=750000 +units=m +ellps=GRS80 +datum=NAD83 +no_defs
```

```
+proj=laea +lat_0=45 +lon_0=-100 +a=6370997 +b=6370997 +no_defs
```

`+proj=lcc +lat_1=42.6833 +lat_2=41.7167 +lat_0=41 +lon_0=-71.5 +x_0=200000 +y_0=750000 +units=m +ellps=GRS80 +datum=NAD83 +no_defs`

+proj=lcc

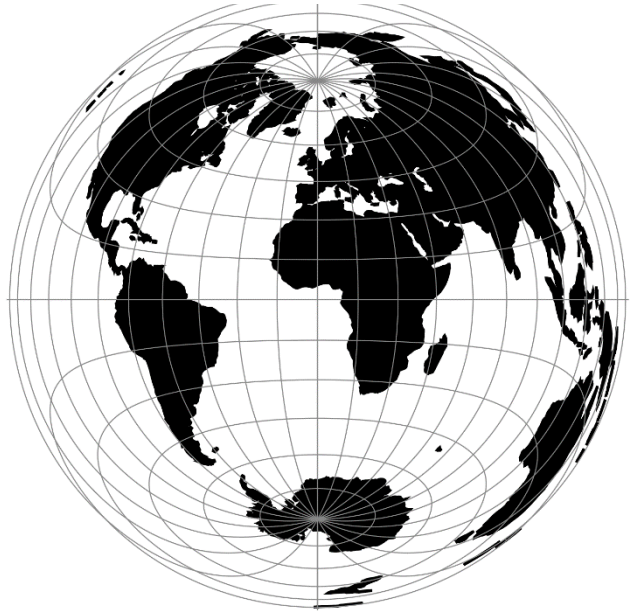
Lambert Conformal Conic projection.



`+proj=laea +lat_0=45 +lon_0=-100 +a=6370997 +b=6370997 +units=m +no_defs`

+proj=laea

Lambert Azimuthal Equal Area projection

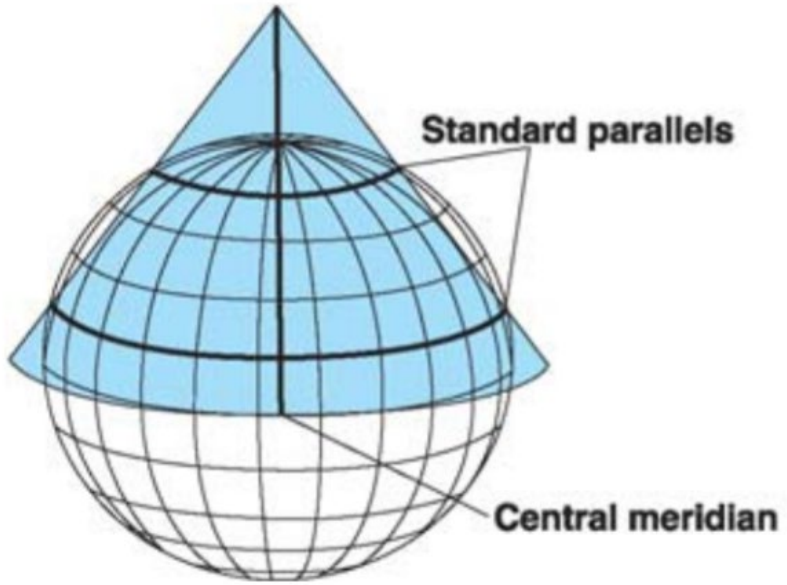


See https://proj.org/operations/projections/index.html for a list of 142 possible projections to choose from, with details about each.

```
+proj=lcc +lat_1=42.6833 +lat_2=41.7167 +lat_0=41 +lon_0=-71.5 +x_0=200000 +y_0=750000 +units=m +ellps=GRS80 +datum=NAD83 +no_defs
```

+ lat_1=42.6833 +lat_2=41.7167

Standard parallels are at 42.6833° and 41.7167°




```
+proj=laea +lat_0=45 +lon_0=-100 +a=6370997 +b=6370997 +no_defs
```

No standard parallels, plane is tangent at a single point

+proj=lcc +lat_1=42.6833 +lat_2=41.7167 +lat_0=41 +lon_0=-71.5 +x_0=200000 +y_0=750000 +units=m +ellps=GRS80 +datum=NAD83 +no_defs

+lat_0=41 +lon_0=-71.5

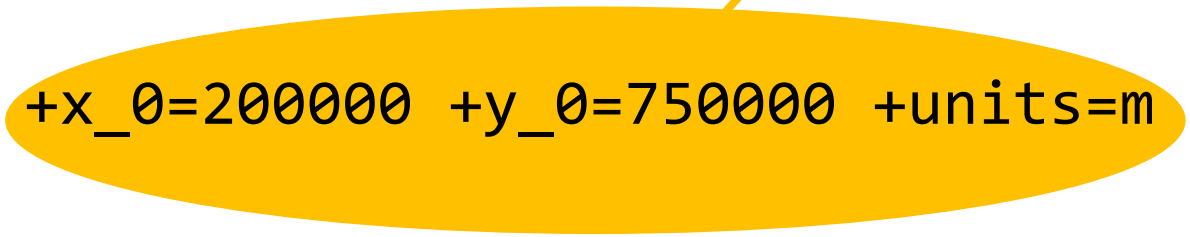
Projection centered at 41º latitude, -71.5º longitude

+proj=laea +lat_0=45 +lon_0=-100 +a=6370997 +b=6370997 +no_defs

+lat_0=45 +lon_0=-100

Projection centered at 45º latitude, -100º longitude

```
+proj=lcc +lat_1=42.6833 +lat_2=41.7167 +lat_0=41 +lon_0=-71.5 +x_0=200000 +y_0=750000 +units=m +ellps=GRS80 +datum=NAD83 +no_defs
```



Move the origin from the central meridian / equator to a
Point south west of Massachusetts, and express units in meters.

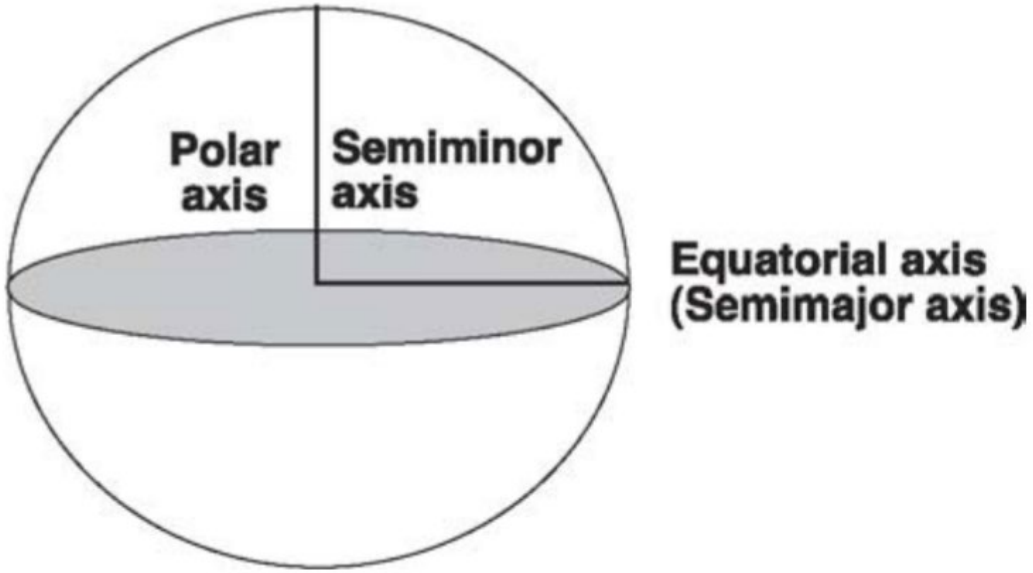
```
+proj=laea +lat_0=45 +lon_0=-100 +a=6370997 +b=6370997 +no_defs
```

Coordinates still expressed as latitude/longitude

```
+proj=lcc +lat_1=42.6833 +lat_2=41.7167 +lat_0=41 +lon_0=-71.5 +x_0=200000 +y_0=750000 +units=m +ellps=GRS80 +datum=NAD83 +no_defs
```

+ellps=GRS80

Use the standard spheroid for the Geodetic Reference System of 1980 (major radius is 6,378,137 meters, minor radius is 6,356,752 meters)




```
+proj=laea +lat_0=45 +lon_0=-100 +a=6370997 +b=6370997 +no_defs
```

+ a=6370997 +b=6370997

Use spheroid with a major radius of 6,370,997 meters, minor radius of 6,370,997 meters

```
+proj=lcc +lat_1=42.6833 +lat_2=41.7167 +lat_0=41 +lon_0=-71.5 +x_0=200000 +y_0=750000 +units=m +ellps=GRS80 +datum=NAD83 +no_defs
```

+datum=NAD83

Shift the center of the spheroid to be more accurate for North America (North American Datum of 1983).

```
+proj=laea +lat_0=45 +lon_0=-100 +a=6370997 +b=6370997 +no_defs
```

Earth-centered datum