

SEST-6577

Geographic Information Systems for Security Studies

Lecture 02 (Map Projections and Overlays)

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Outline

1. Measuring the Earth
2. Cartography and Map Overlays

Measuring the Earth

Where are we?

- latitude: 38.90894,
- longitude: -77.07458

but what does that mean?

1. Latitude (vertical coordinate)

- ϕ ("phi"): angle between equator & straight line from center of Earth to location
- positive in Northern hemisphere
- negative in Southern hemisphere

2. Longitude (horizontal coordinate)

- λ ("lambda"): angle between Prime Meridian & straight line from center of Earth to location
- positive east of Prime Meridian
- negative west of Prime Meridian

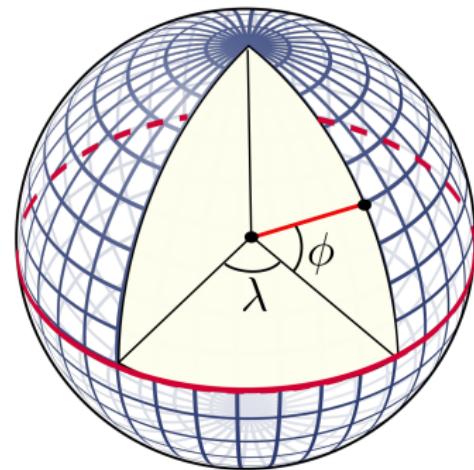


Figure 1: ϕ = lat, λ = lon

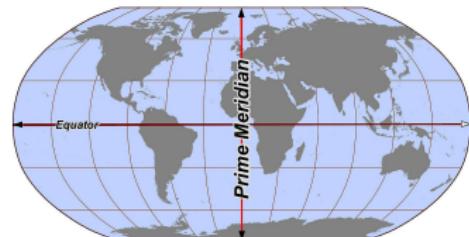


Figure 2: Prime Meridian

The Shape of Earth

What is the shape of the earth?

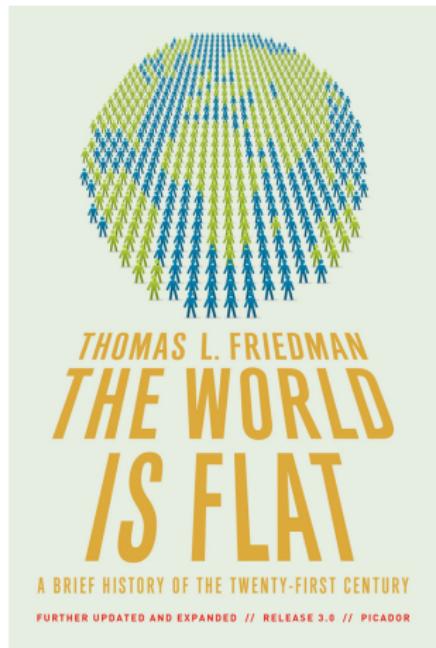


Figure 3: Wrong!



It's Turtles
All The Way Down.

Figure 4: Wrong!

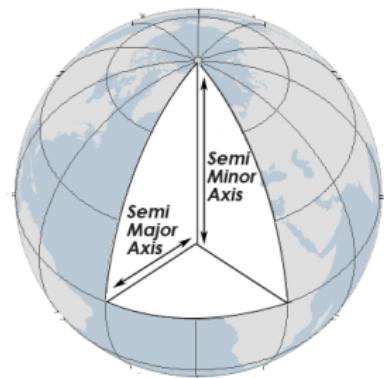
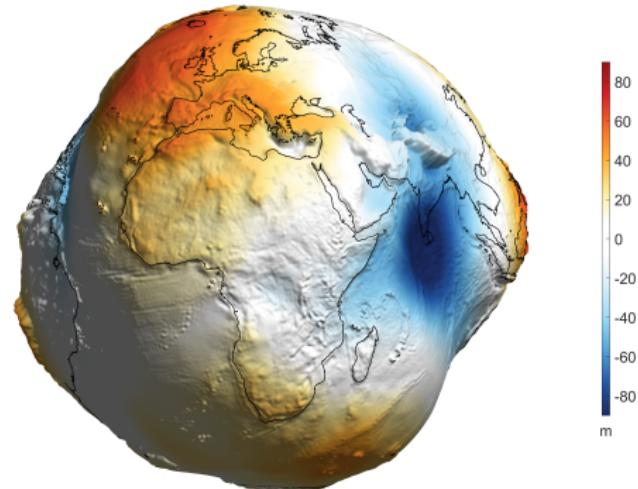


Figure 5: Also wrong?

1. Geoid

- a) surface of equal gravitational potential (\sim mean sea level)
- b) measured, interpolated surface



Geoid height (EGM2008, nmax=1000)

Figure 6: Geoid

2. Ellipsoid

- a) ellipsoidal model that is best fit to Earth's shape
- b) ellipsoid = ellipse rotated around its short axis

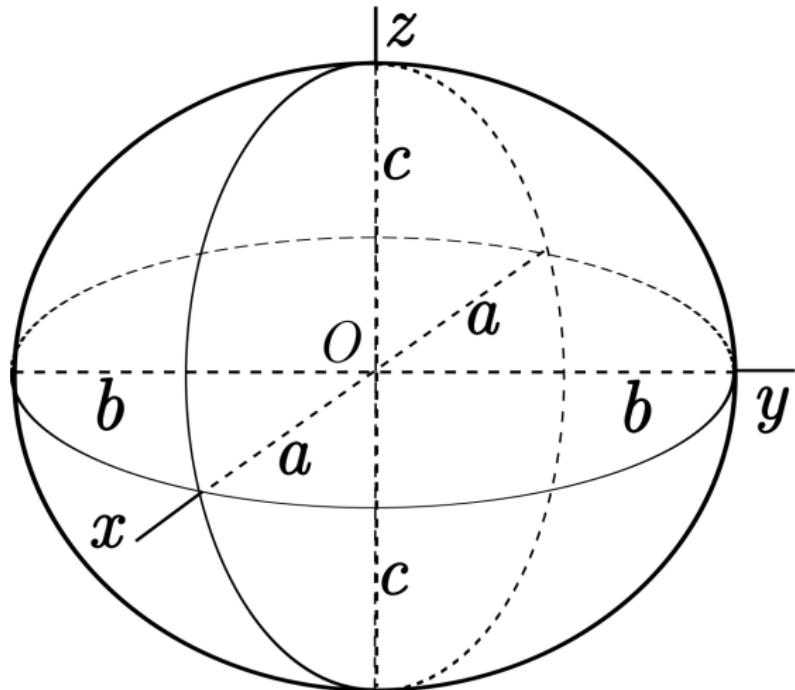


Figure 7: Ellipsoid

3. Topography

- a) Earth's height, relative to mean sea level
- b) measured with satellite or aerial photography

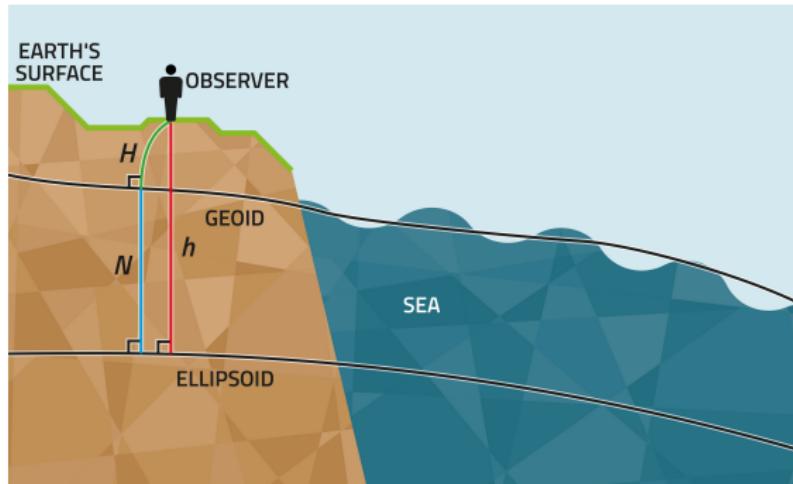


Figure 8: Topography vs. Geoid vs. Ellipsoid

Geodetic datum

- coordinate system that references ellipsoid to geoid
- examples:

ellipsoid	datum
WGS 1984	NAD 1983
Clarke 1866	NAD 1927

- translates positions on maps to real positions on Earth



Figure 9: Geodetic survey marker

World Geodetic System 1984

- international standard for GPS, satellite navigation systems
- developed by DoD, international network of scientists
- refinement of GRS 80 reference ellipsoid
- associated with North American Datum 1983 (NAD 1983)
- radius at Equator = 6378.14 km
- default in most GIS

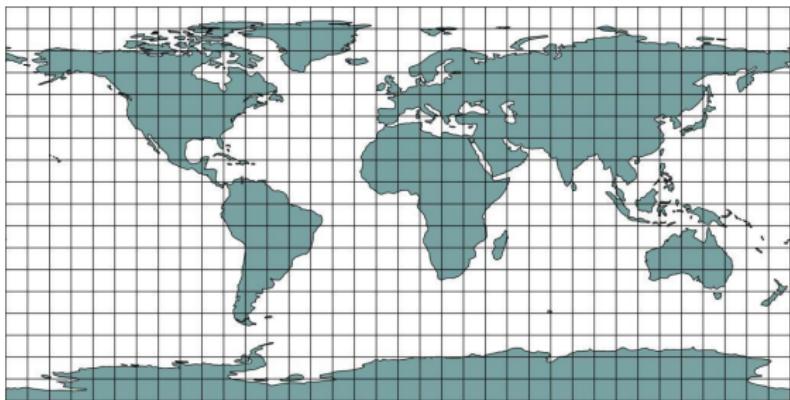


Figure 10: WGS 84

Projections and Coordinate Systems



Figure 11: How to squeeze 3 dimensions into 2?

What are projections?

- transformations from Earth's 3D surface to 2D plane
1. *Cylindrical projection*
 - "wrap cylinder around Equator"
 - more distortion near poles
 2. *Conic projection*
 - "put cone on top of Earth"
 - latitudes as arcs, longitude as straight lines
 3. *Azimuthal projection*
 - "put flat plane on top of Earth"
 - projection outward from single central point

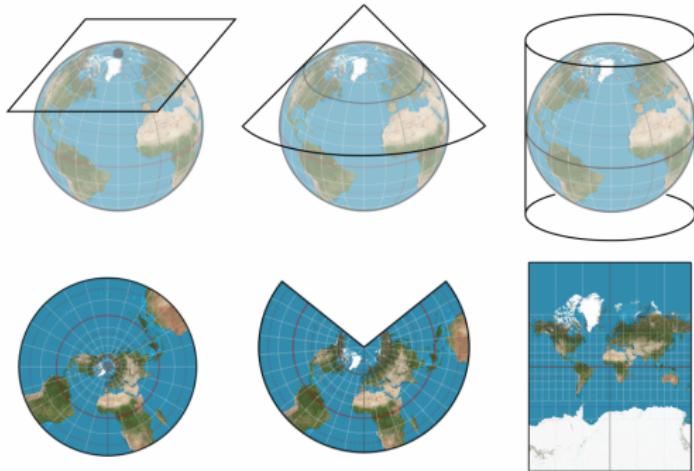


Figure 12: Azimuth, cone, cylinder

4. “Unprojected” projection

- raw geographic coordinates
- latitude → vertical axis
- longitude → horizontal axis
- effectively a cylindrical projection
- less distortion near Equator
- more distortion near poles

Map 1: Projected and Unprojected Maps of the World

Rachel Ruthven, Feb. 2, 2016

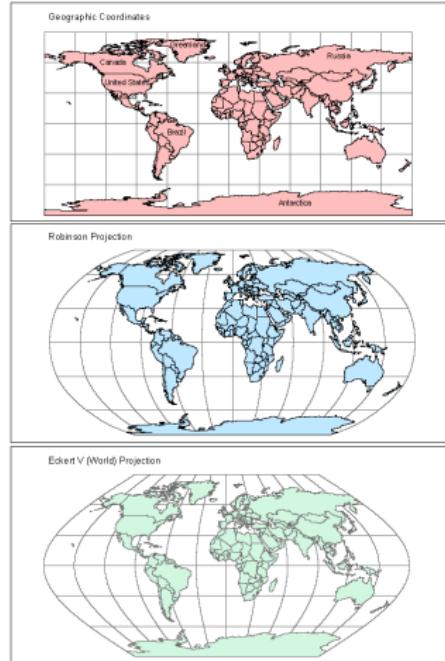


Figure 13: No free lunch

Distortion

- all projections distort Earth
- area, distance, direction, shape

1. Conformal/conic projections

(e.g. Lambert Conformal Conic)

- preserves angles, shapes
- distorts area

2. Equal area projections

(e.g. Albers Conic Equal Area)

- preserves area
- distorts angles, shapes

3. Azimuthal projections

(e.g. Azimuthal Equidistant)

- preserves direction, distance
- distorts shapes

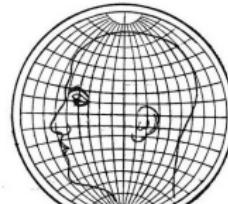


FIG. 42.—Man's head drawn on globular pro-
jection.

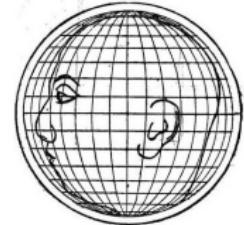


FIG. 43.—Man's head plotted on orthographic pro-
jection.

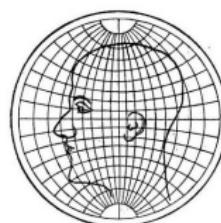


FIG. 44.—Man's head plotted on stereographic
projection.

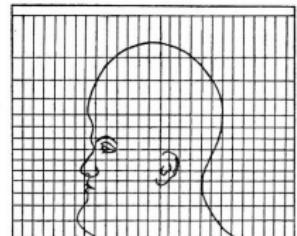


FIG. 45.—Man's head plotted on Mercator projec-
tion.

Figure 14: Funhouse mirrors

Common coordinate systems

1. *Universal Transverse Mercator (UTM)*
 - global system of 60 zones
 - cylindrical projection

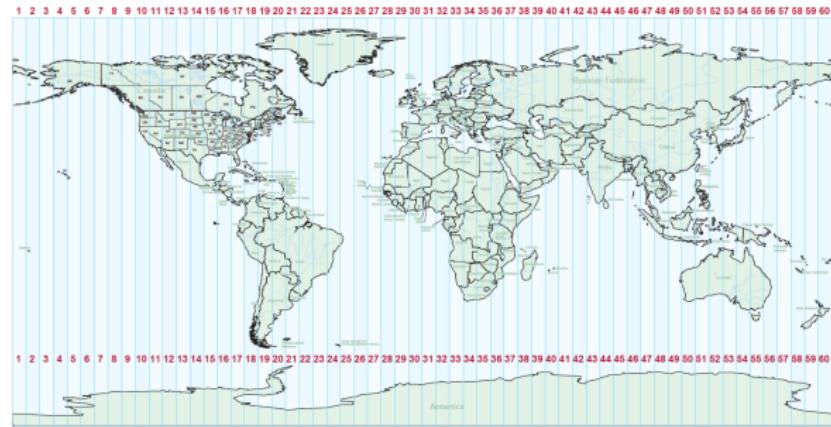


Figure 15: UTM

2. Military Grid Reference System (MGRS)

- derived from UTM, with different labeling convention
- NATO military standard

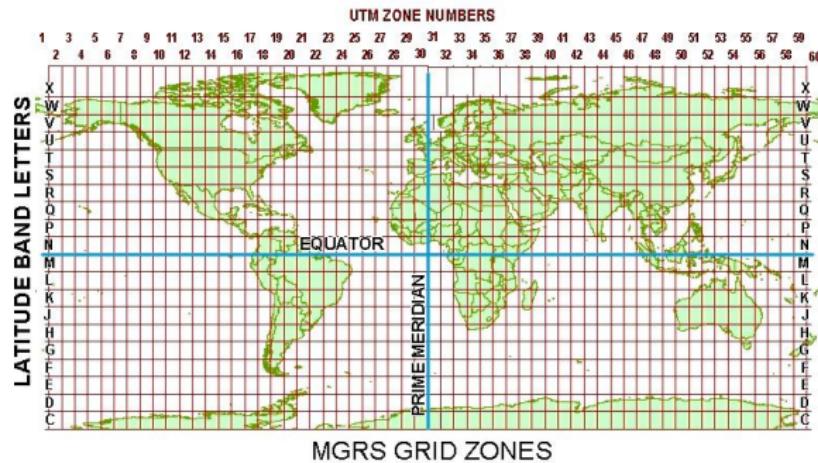


Figure 16: MGRS

3. State Plane Coordinate Systems

- defined separately for each U.S. state
- high local accuracy

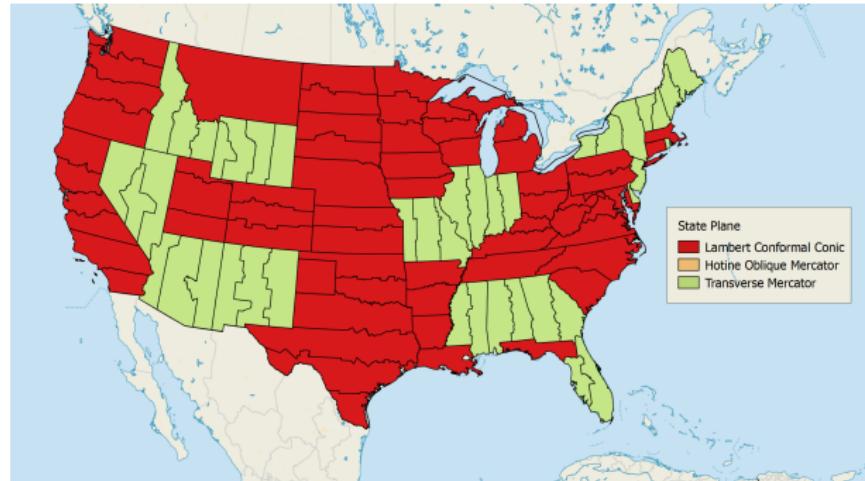
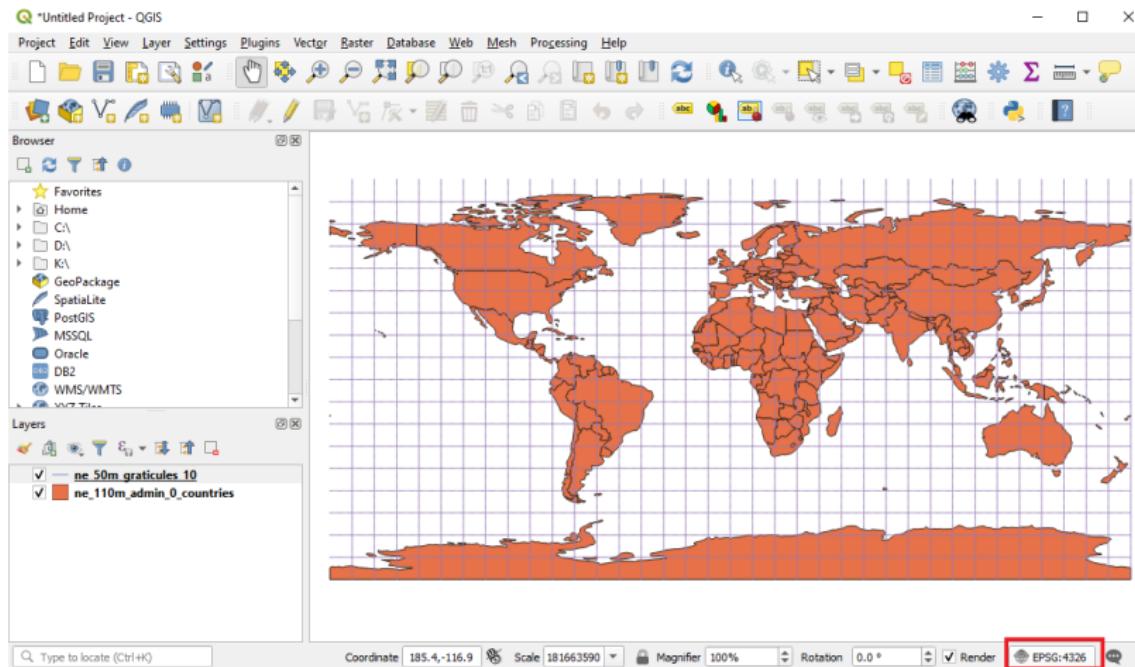


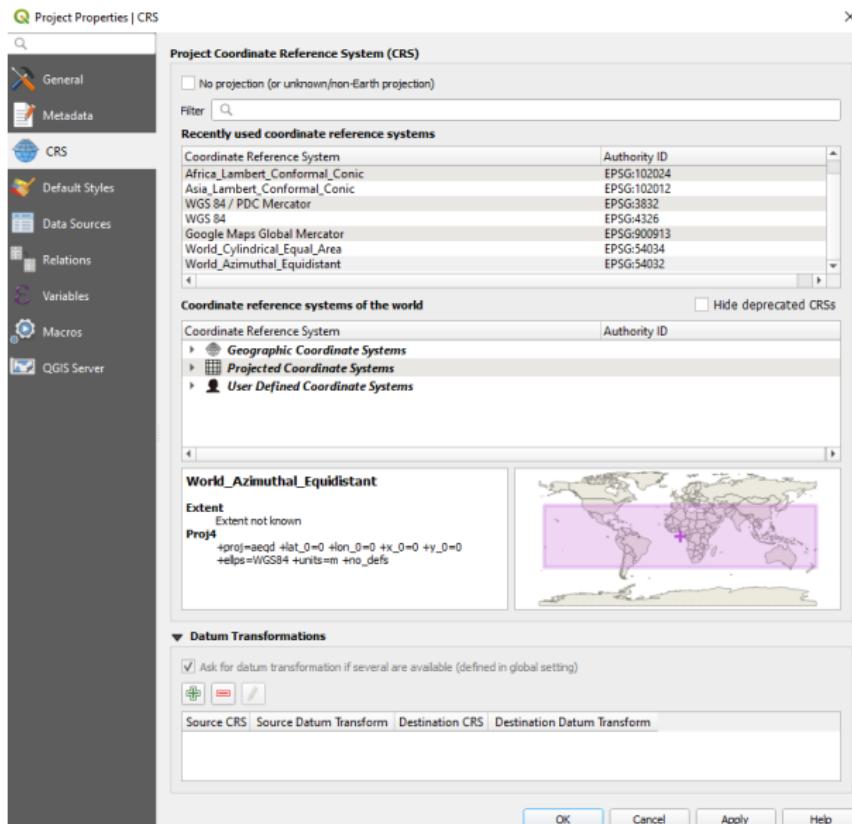
Figure 17: SPRS

In QGIS, your map's projection information is found in the lower-right corner
(EPSG = European Petroleum Survey Group code)

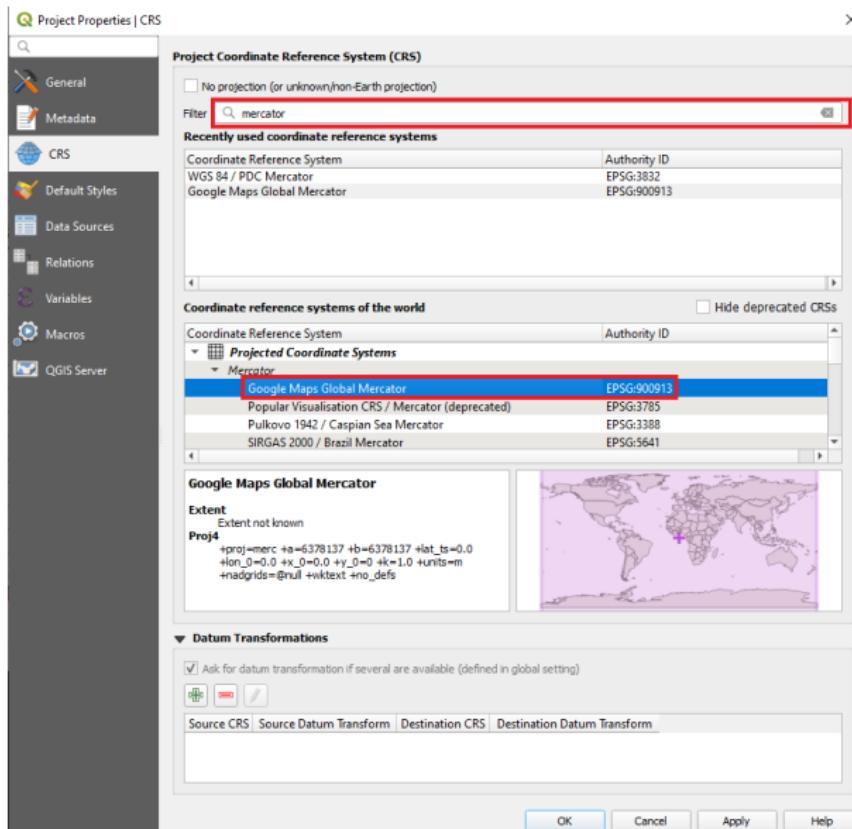
- EPSG:4326 is the code for World Geodetic System (WGS84)
- this is the default in QGIS, and a standard for satellite navigation systems



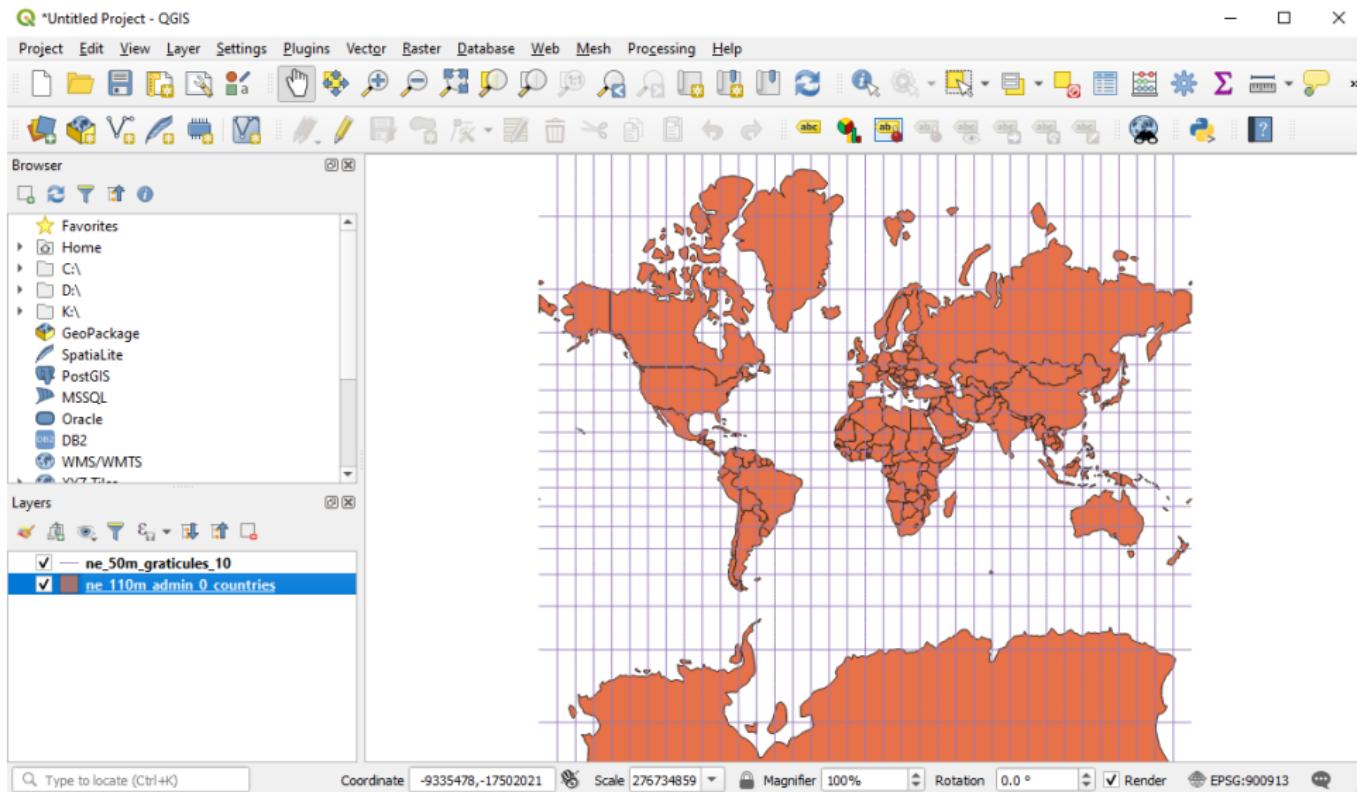
Click on the EPSG code to open CRS Properties (Coordinate Reference System)



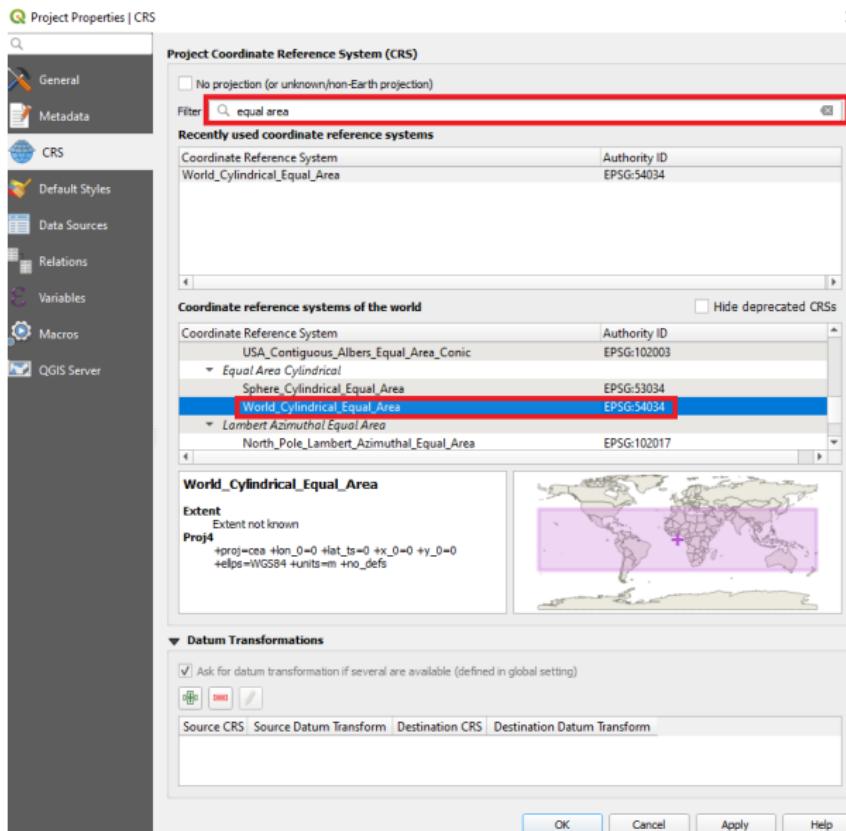
Let's change the CRS to *Mercator* (e.g. EPSG:900913, EPSG:3785). Click OK.



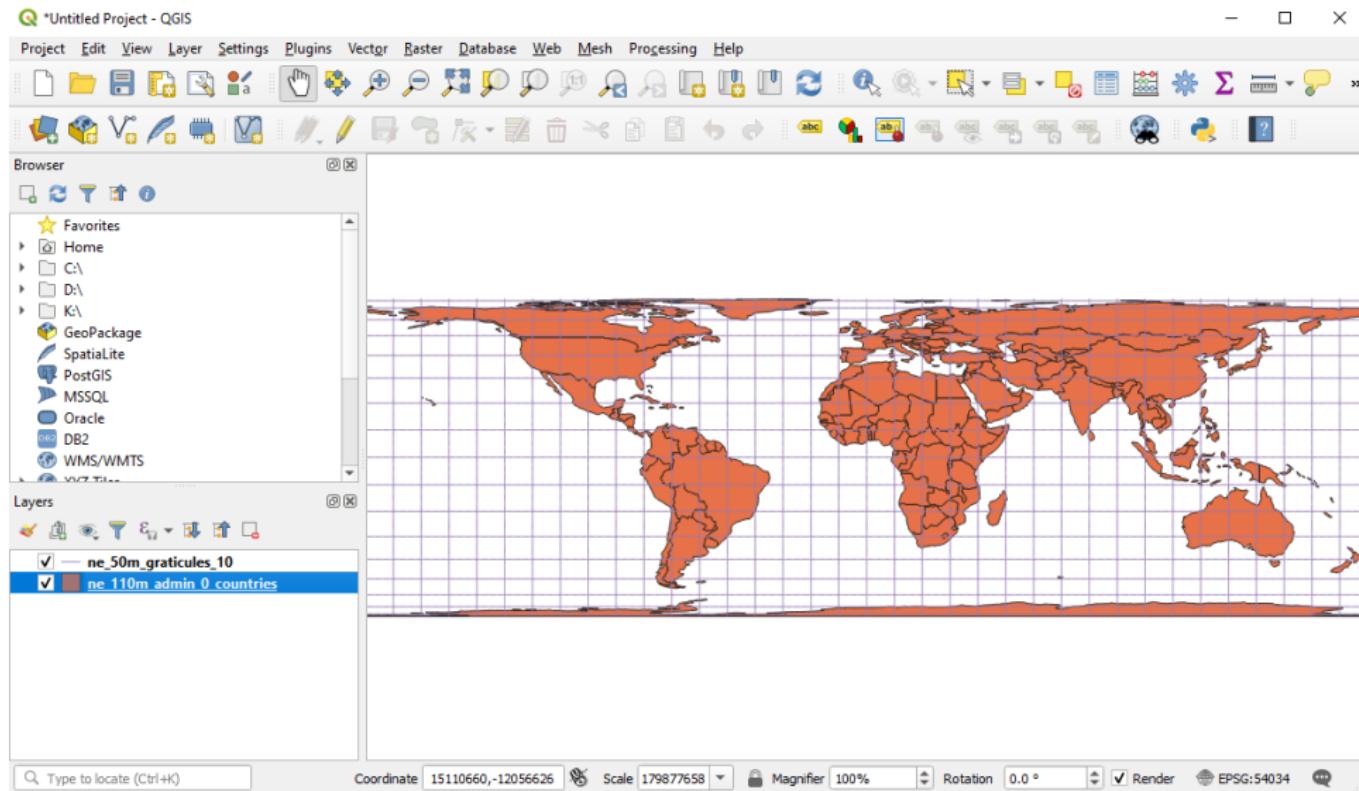
Greenland should now appear larger than the entire continent of Africa...



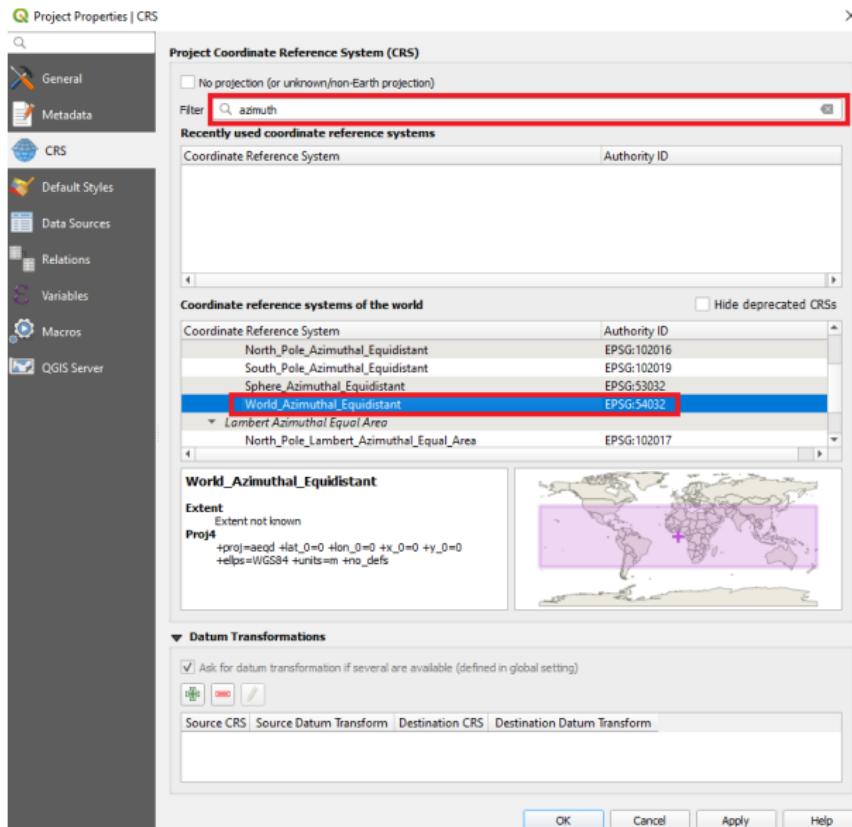
Let's change the CRS to *Equal Area* (EPSG:54034, EPSG:5070).



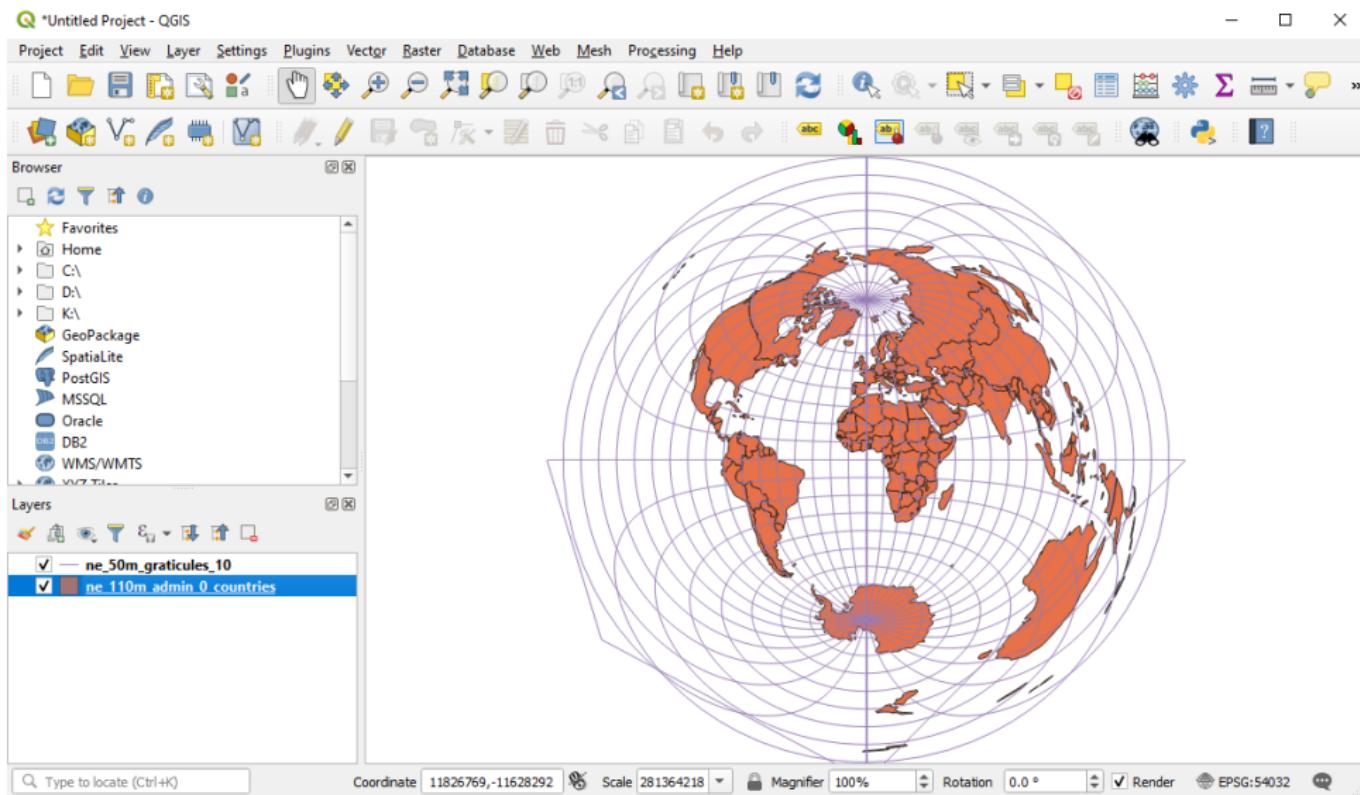
Greenland shrinks. Overcorrection or no?



Let's change the CRS to *World Azimuthal Equidistant* (EPSG:54032).



Now it looks more like a globe than a map... but better for studying the Arctic.



Here's how to check and change projections in R.

Suppose we have 2 sf objects: `world` (world map) and `grat` (graticules).

```
world = sf::read_sf("Data/World/ne_110m_admin_0_countries.geojson")
grat = sf::read_sf("Data/World/ne_50m_graticules_10.geojson")
```

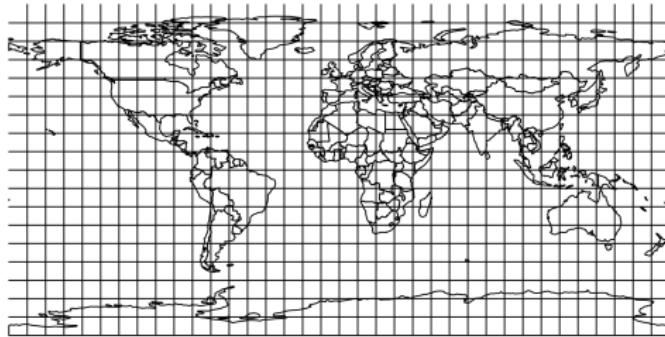
Linking to GEOS 3.10.2, GDAL 3.4.1, PROJ 8.2.1; `sf_use_s2()` is TRUE
We can check their CRS with `st_crs()` from the `sf` library.

```
sf::st_crs(world)

## Coordinate Reference System:
##   User input: WGS 84
##   wkt:
##   GEOCRS["WGS 84",
##          DATUM["World Geodetic System 1984",
##                 ELLIPSOID["WGS 84",6378137,298.257223563,
##                           LENGTHUNIT["metre",1]],
##                 PRIMEM["Greenwich",0,
##                         ANGLEUNIT["degree",0.0174532925199433]],
##                 CS[ellipsoidal,2],
##                   AXIS["geodetic latitude (Lat)",north,
##                         ORDER[1],
##                         ANGLEUNIT["degree",0.0174532925199433]],
##                   AXIS["geodetic longitude (Lon)",east,
##                         ORDER[2],
##                         ANGLEUNIT["degree",0.0174532925199433]],
##                   ID["EPSG",4326]]]
```

Here's how these datasets look unprojected (WGS 84).

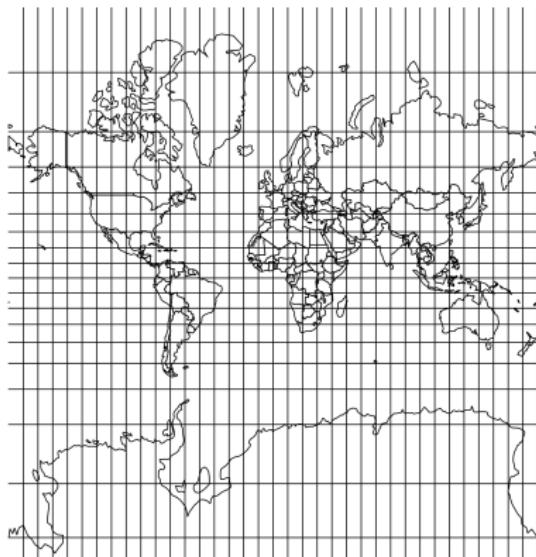
```
plot(world["geometry"], reset=FALSE)  
plot(grat["geometry"], add=TRUE)
```



We can change projections with the `st_transform()` function (`sf` library).

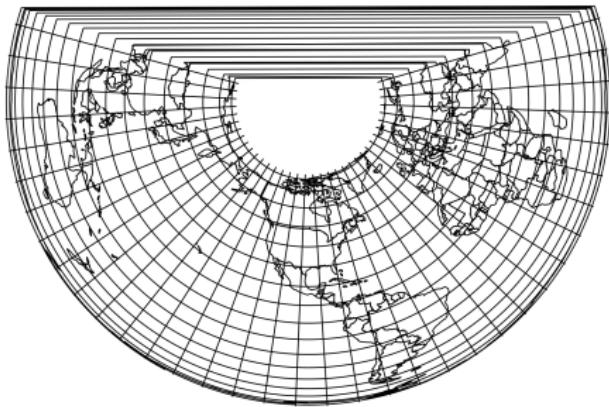
Let's transform to *Mercator* projection (e.g. EPSG:3785), and plot the result.

```
world_ = sf::st_transform(world, crs="EPSG:3785")
grat_ = sf::st_transform(grat, crs="EPSG:3785")
plot(world_[ "geometry" ], reset=FALSE)
plot(grat_[ "geometry" ], add=TRUE)
```



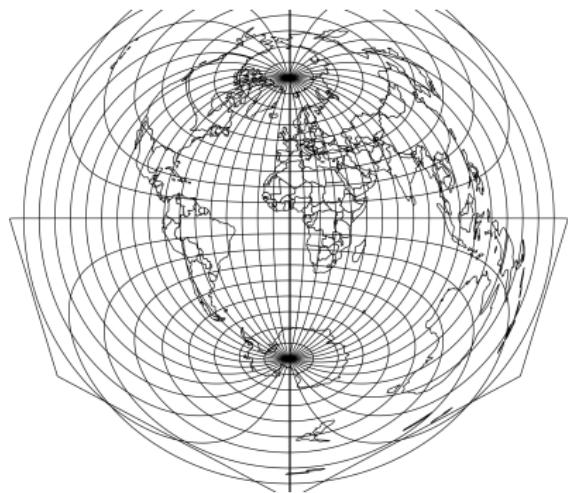
Let's transform to *Equal Area* projection (e.g. EPSG:5070).

```
world_ = sf::st_transform(world, crs="EPSG:5070")
grat_ = sf::st_transform(grat, crs="EPSG:5070")
plot(world_[ "geometry"] ,reset=FALSE)
plot(grat_[ "geometry"] ,add=TRUE)
```



Let's transform to *Azimuthal Equidistant* projection (e.g. ESRI:54032).

```
world_ = sf::st_transform(world, crs="ESRI:54032")
grat_ = sf::st_transform(grat, crs="ESRI:54032")
plot(world_[ "geometry" ], reset=FALSE)
plot(grat_[ "geometry" ], add=TRUE)
```



You can **look up a projection's EPSG code** here: spatialreference.org

Cartography and Map Overlays

Overlays

What is an overlay?

- combination of multiple layers of spatial data
- each layer represent some set of features of the real world
 - (e.g. elevation, roads, violence)
- when superimposed on top of each other, layers can reveal patterns and relationships between variables
 - (e.g. are mountainous areas more violent?)
- all layers must be on a common projection!

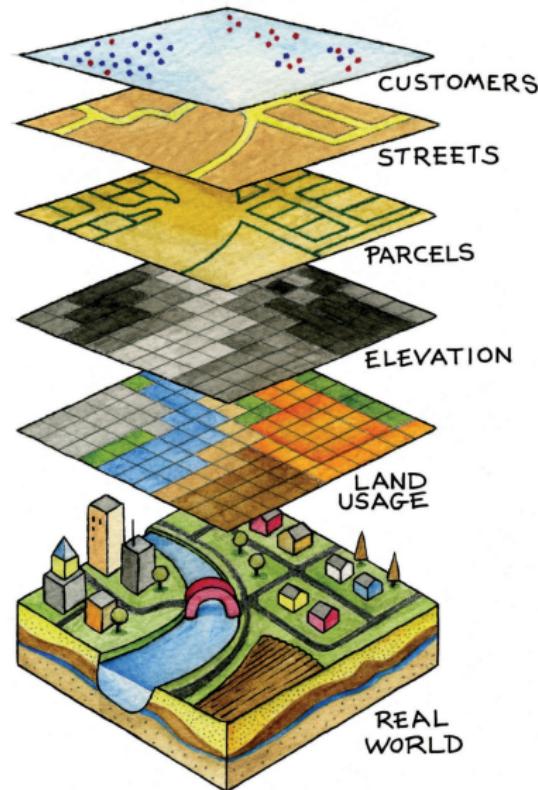


Figure 18: Multiple layers

This week's lab will be focused on map overlays

Michigan 2020 Presidential Election Results

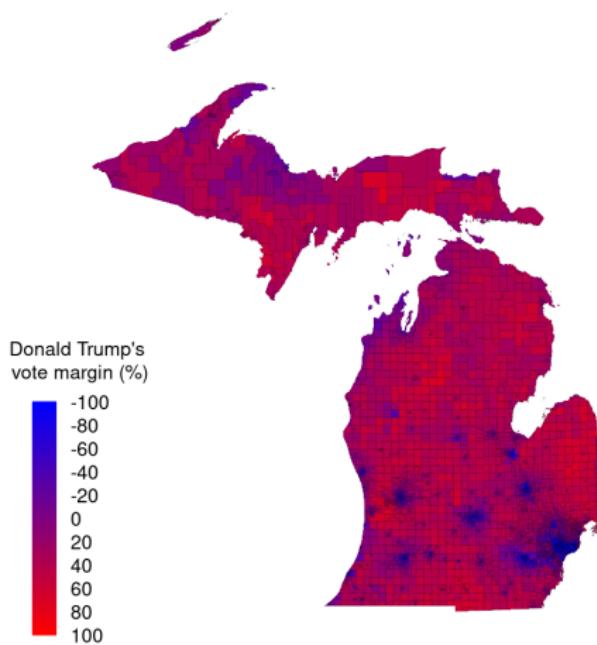


Figure 19: Last week: Single-layer map

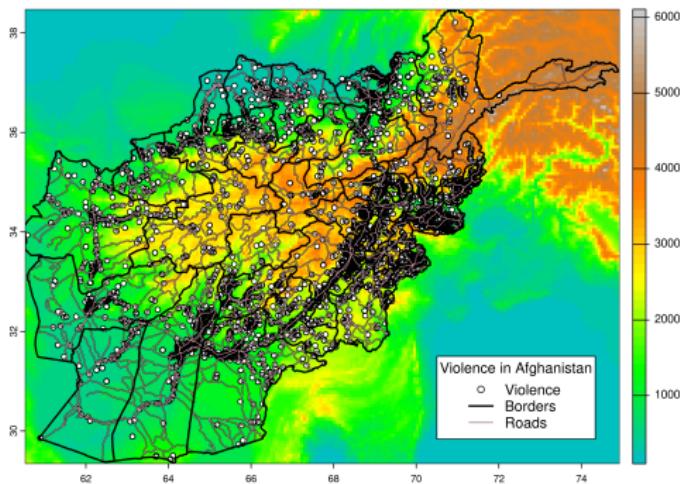


Figure 20: This week: Multi-layer map

What Makes a Good Map?

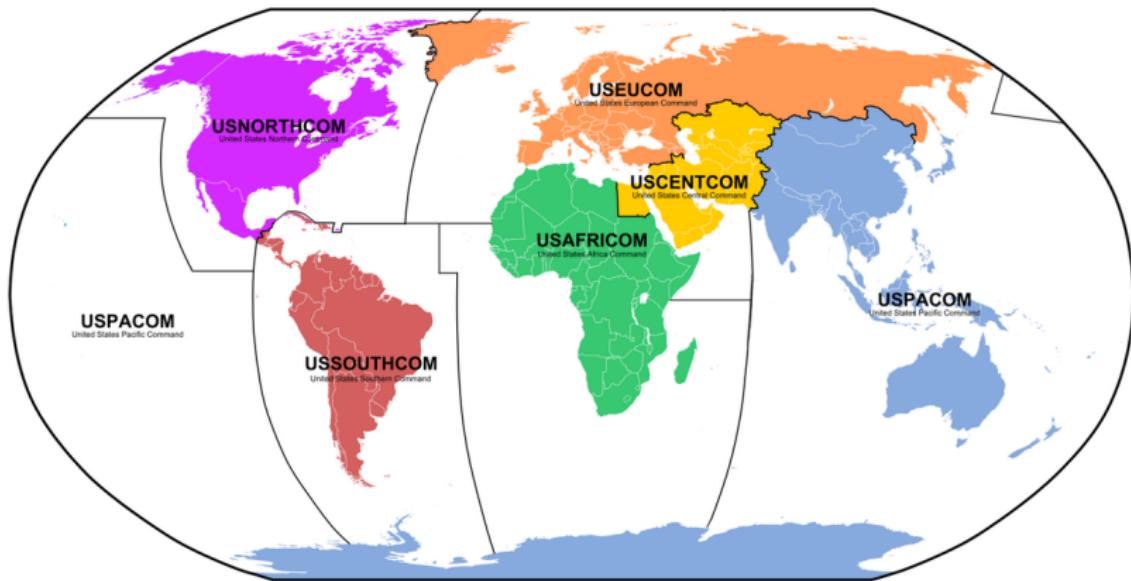


Figure 21: AOR's of U.S. Combatant Commands

A good map should **clearly communicate information**.

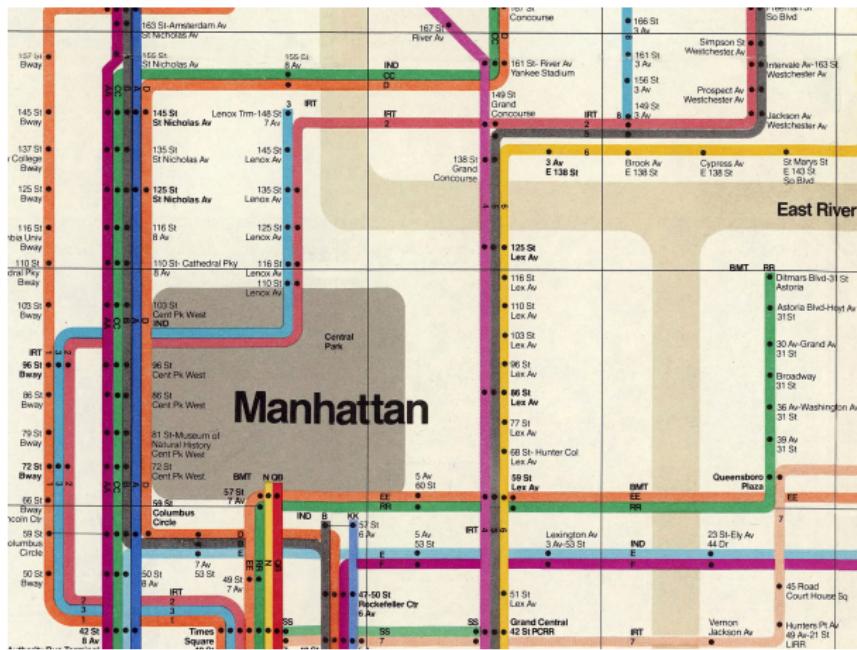


Figure 22: Vignelli's 1972 NYC Subway Map

A good map should direct attention toward information of primary interest.



Figure 23: (Bad) Map of Mendocino Complex Fire

A good map should be **not too complex** (especially if audience is general public).

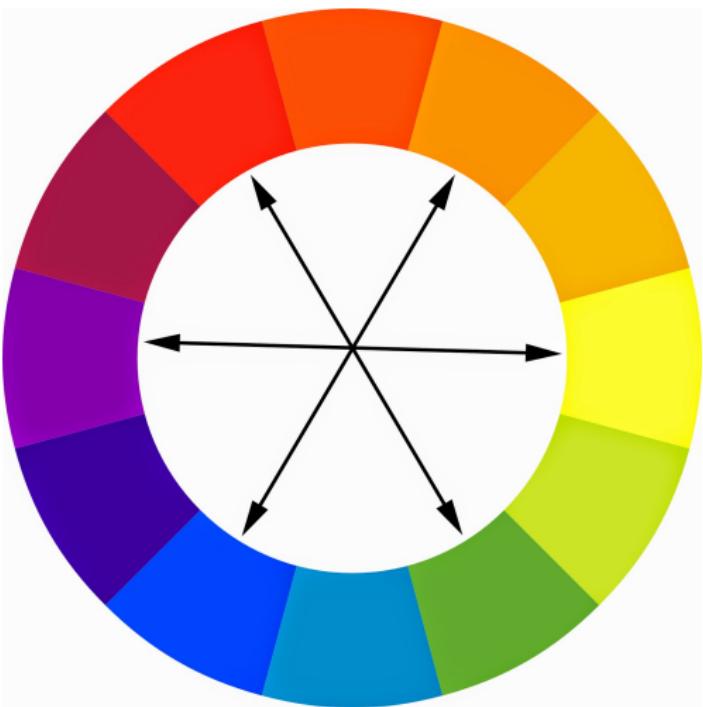


Figure 24: Complementary colors

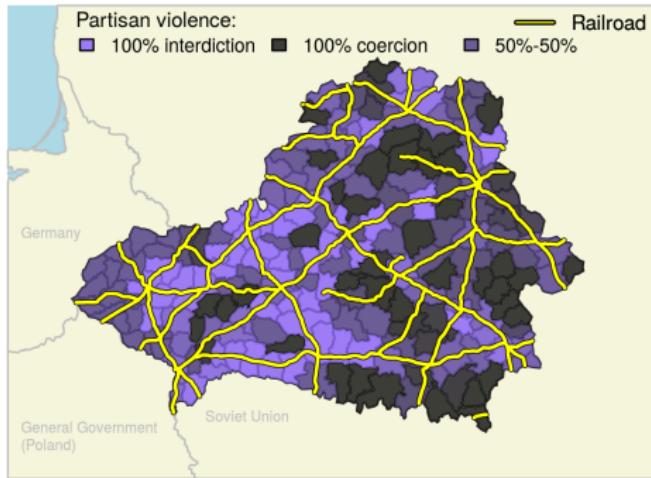


Figure 25: Map with complementary colors

A good map should **use contrasting colors/shades** (e.g. complementary colors).

Primary uses of maps

1. *Reference map*
(general information)



Figure 26: Interstate highways around NYC

2. *Thematic map*
(focuses on specific theme/subject)

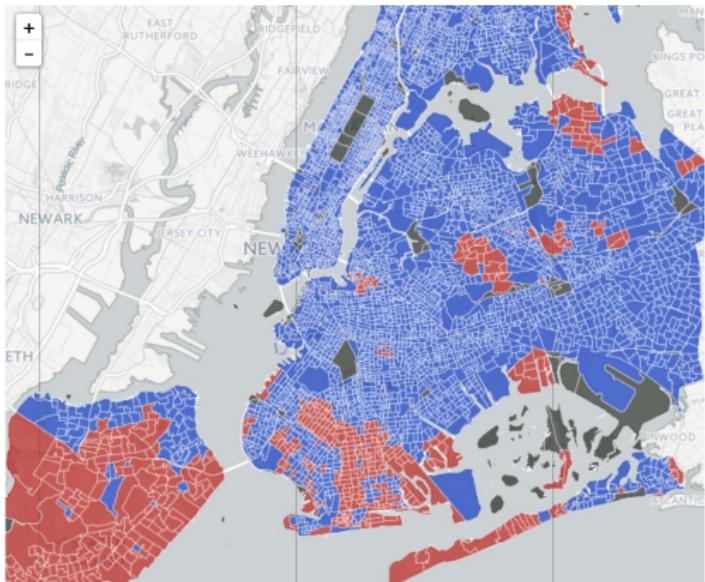


Figure 27: 2016 presidential elections in NYC