Spatial Analysis and Maps with Python

PyCon 2018 Tutorial
5/10/2018
Christy Heaton

FLOYD | SNIDER
strategy • science • engineering

UNIVERSITY of WASHINGTON

python software foundation

About me:

Email: christyheaton@gmail.com
Twitter: @christytoes
Website: christyheaton.github.io

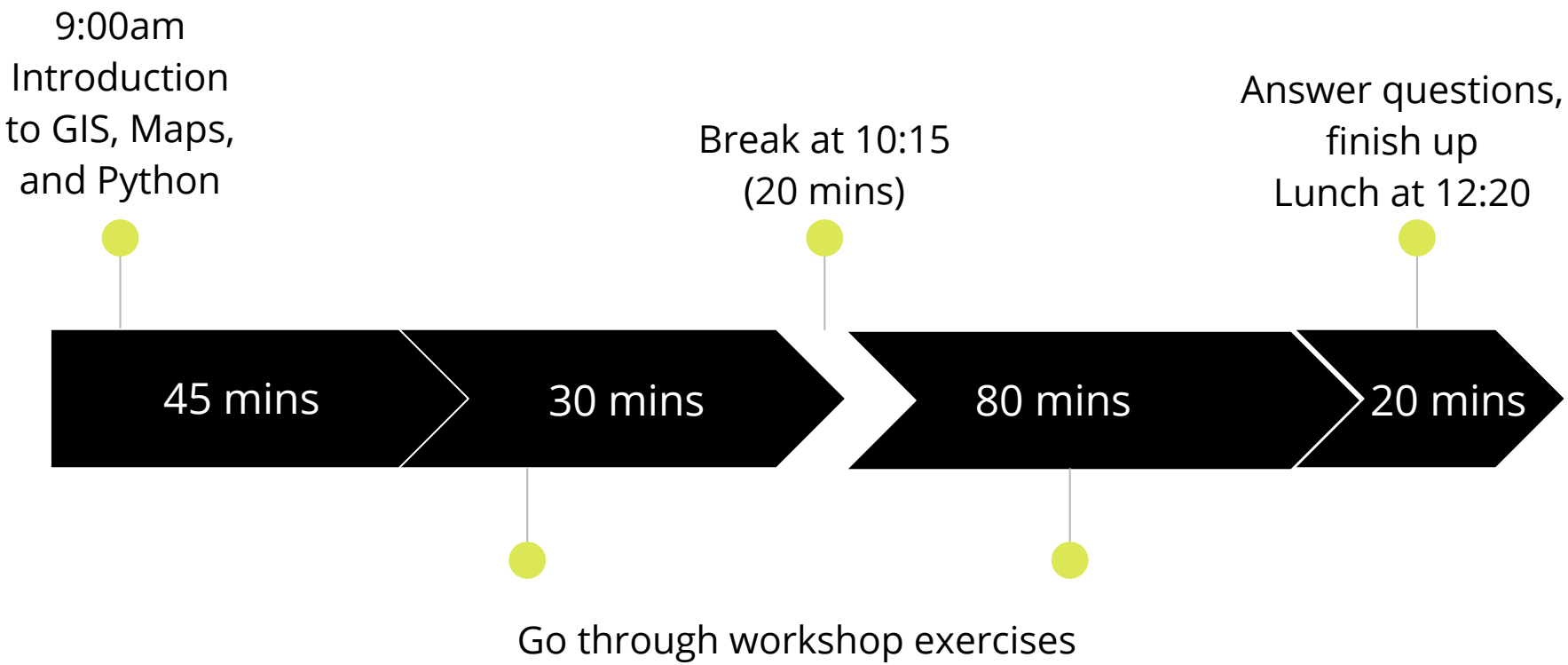
pyladies SEATTLE

PYCON CLEVELAND 2018

PyCon 2018

Intro to Spatial Analysis and Maps with Python

- Novice-level
- Expecting some Python knowledge but no GIS
- https://us.pycon.org/2018/schedule/presentation/65/


9:00am
Introduction
to GIS, Maps,
and Python
Break at 10:15
(20 mins)
Answer questions,
finish up
Lunch at 12:20
45 mins
30 mins
80 mins
20 mins
Go through workshop exercises

Setup

Go here:

https://github.com/christyheaton/PyCon2018_GISTutorial

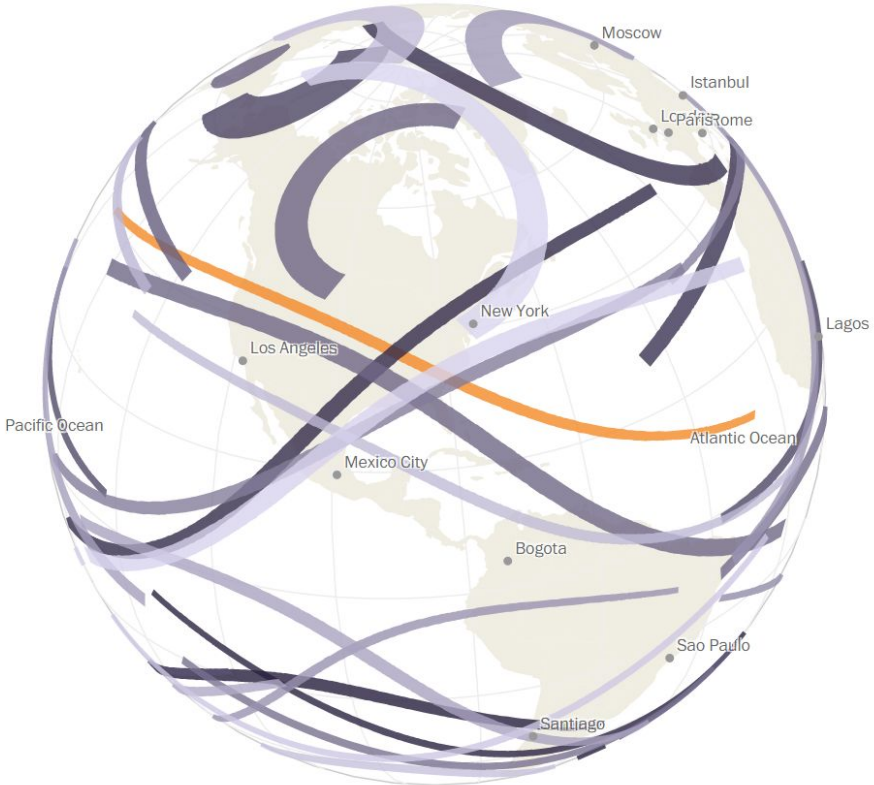
Setup instructions are in the README.

Let’s Talk About Maps

Maps are Useful

https://washington-org.s3.amazonaws.com/s3fs-public/styles/editorial_wide/public/wmata-metro-map.jpg

Maps are Cool

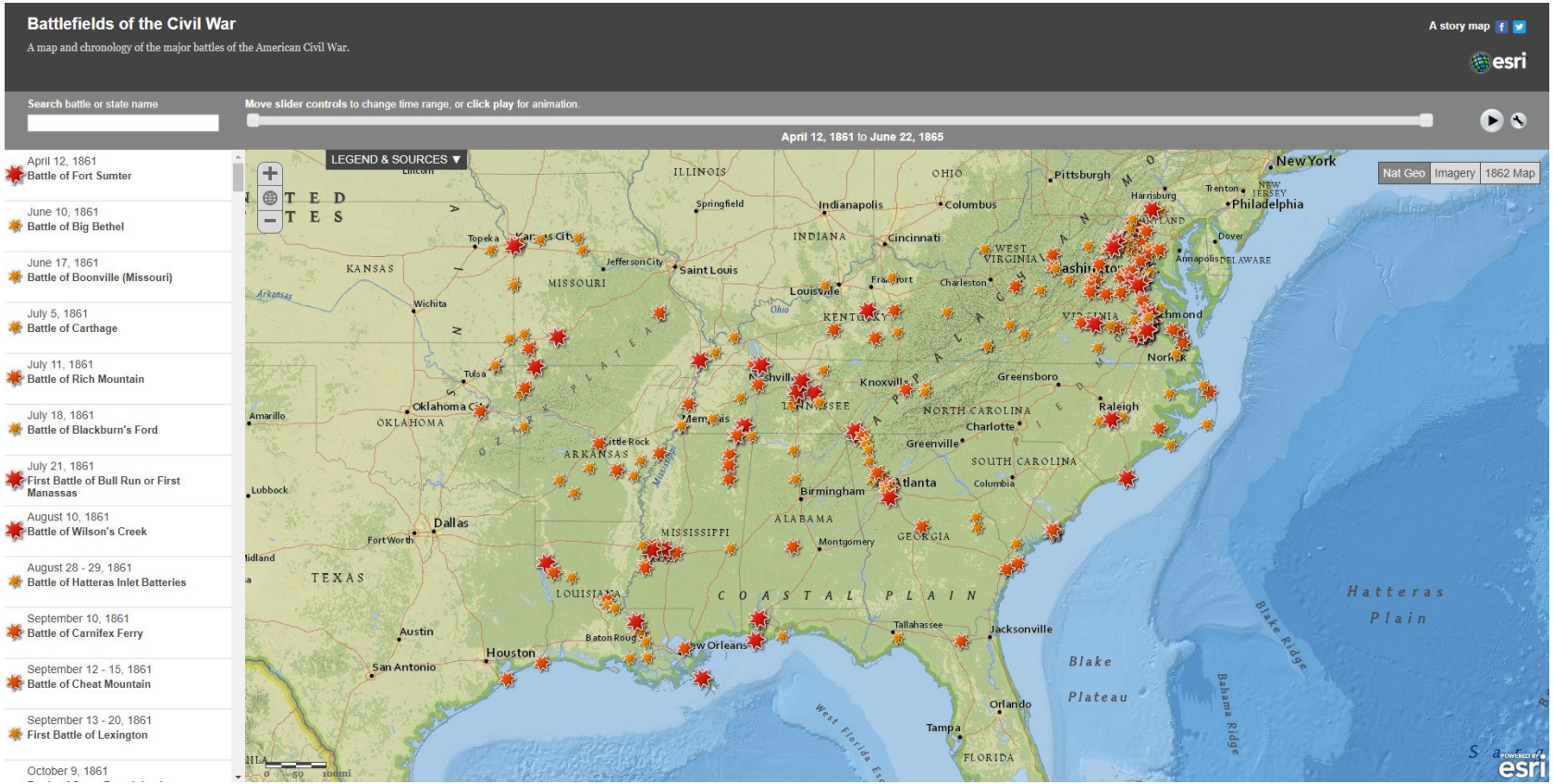


https://www.washingtonpost.com/graphics/national/eclipse/?utm_term=.d2cc157c8de0

Maps are Beautiful

http://1.bp.blogspot.com/-zgKh_iUR1lI/UNJRIdDbZaI/AAAAAAAAIlY/GfBxUOZ3Rd0/s1600/Matthew-Cusick_trendland_2-600x436.jpg

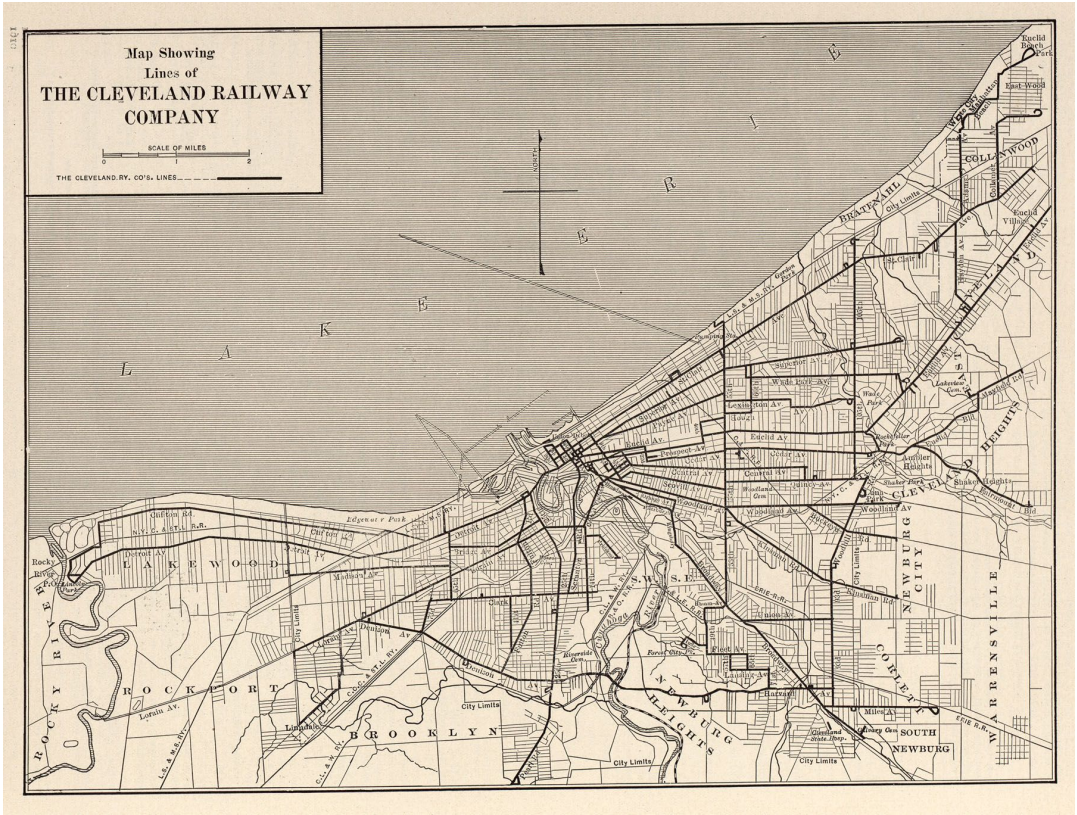
Maps Tell a Story



We Use Maps All The Time

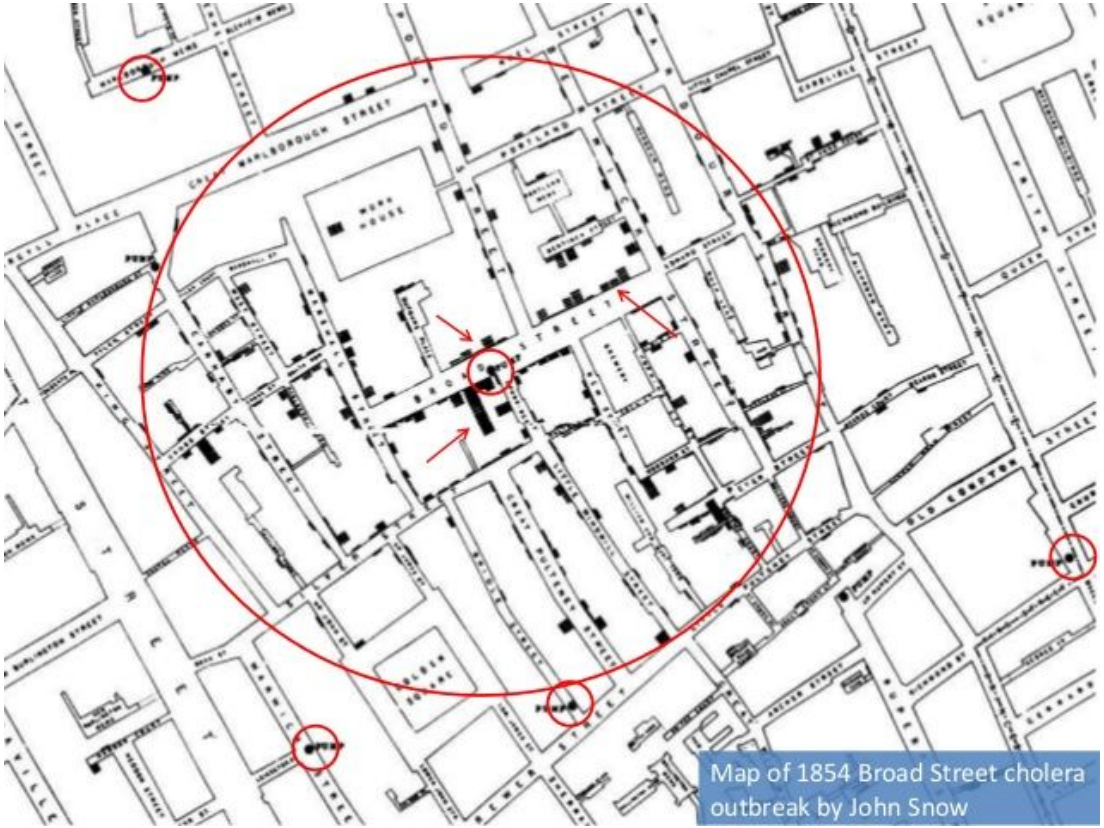
http://cdn-media-1.lifehack.org/wp-content/files/2014/12/Les-multiples-services-de-Waze.png

Maps Have Been Around a While



https://legacy.lib.utexas.edu/maps/historical/txu-oclc-6445490-electric_railway-cleveland-1913.jpg

Mapping for Problem Solving



https://image.slidesharecdn.com/130409-financial-networkscrc-130411091407-phpapp02/95/financial-networks-and-cartography-2-638.jpg?cb=1365671703

“Hasn’t Everything Already Been Mapped?”

“Hasn’t Everything Already Been Mapped?”

```
Not possible
```

Let's Make a Distinction

- Base maps - used for reference
- Thematic maps - have a theme

Base Maps

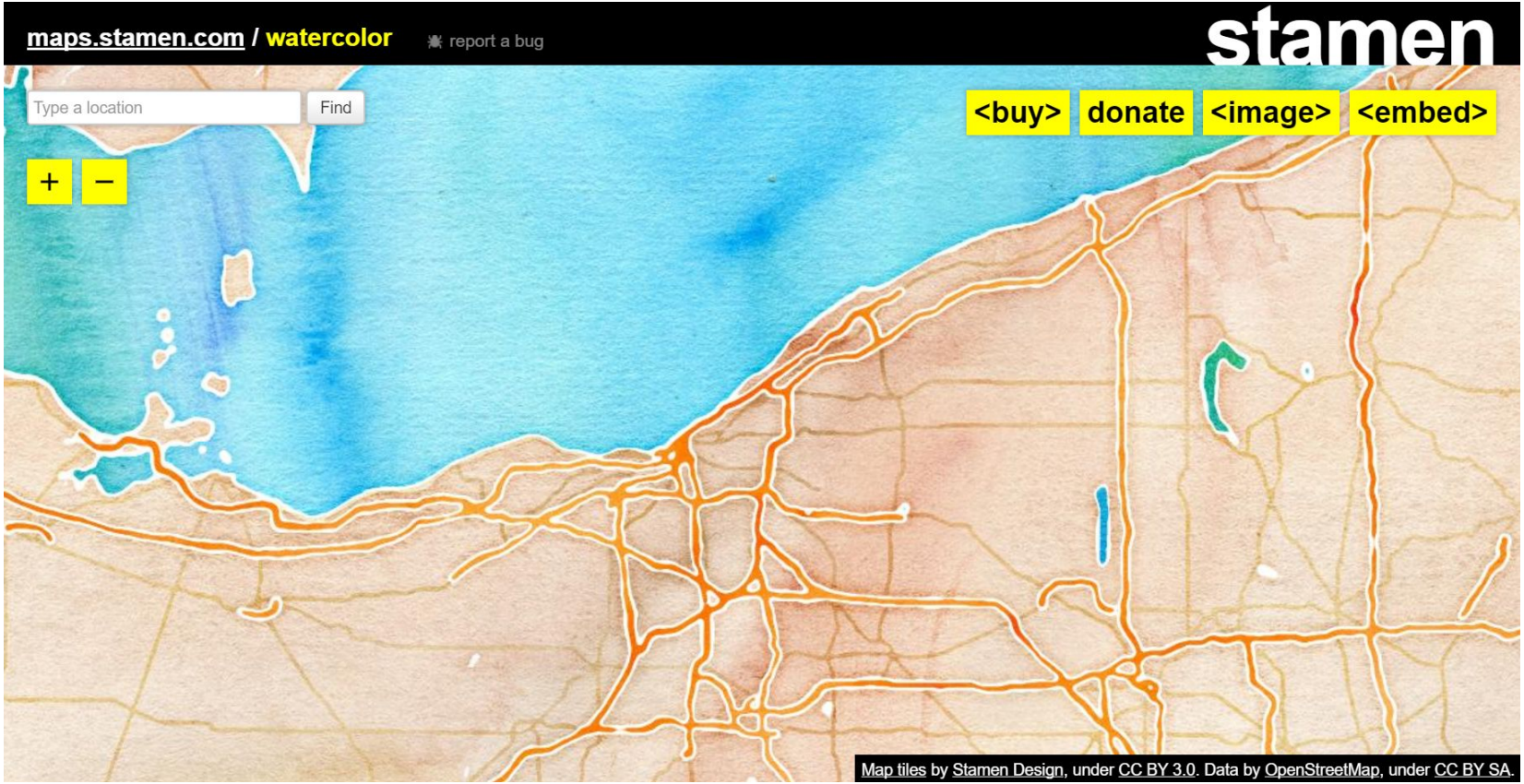
https://www.planet.com/products/basemap

Base Maps

1:7,500,000

1:15,000

Base Maps



http://maps.stamen.com/watercolor/#9/41.6185/-81.5048

Base Maps

- Changes in landscapes and infrastructure

Base Maps

- Changes in landscapes and infrastructure
- Different colors

Base Maps

- Changes in landscapes and infrastructure
- Different colors
- Different scales

Base Maps

- Changes in landscapes and infrastructure
- Different colors
- Different scales
- Different features

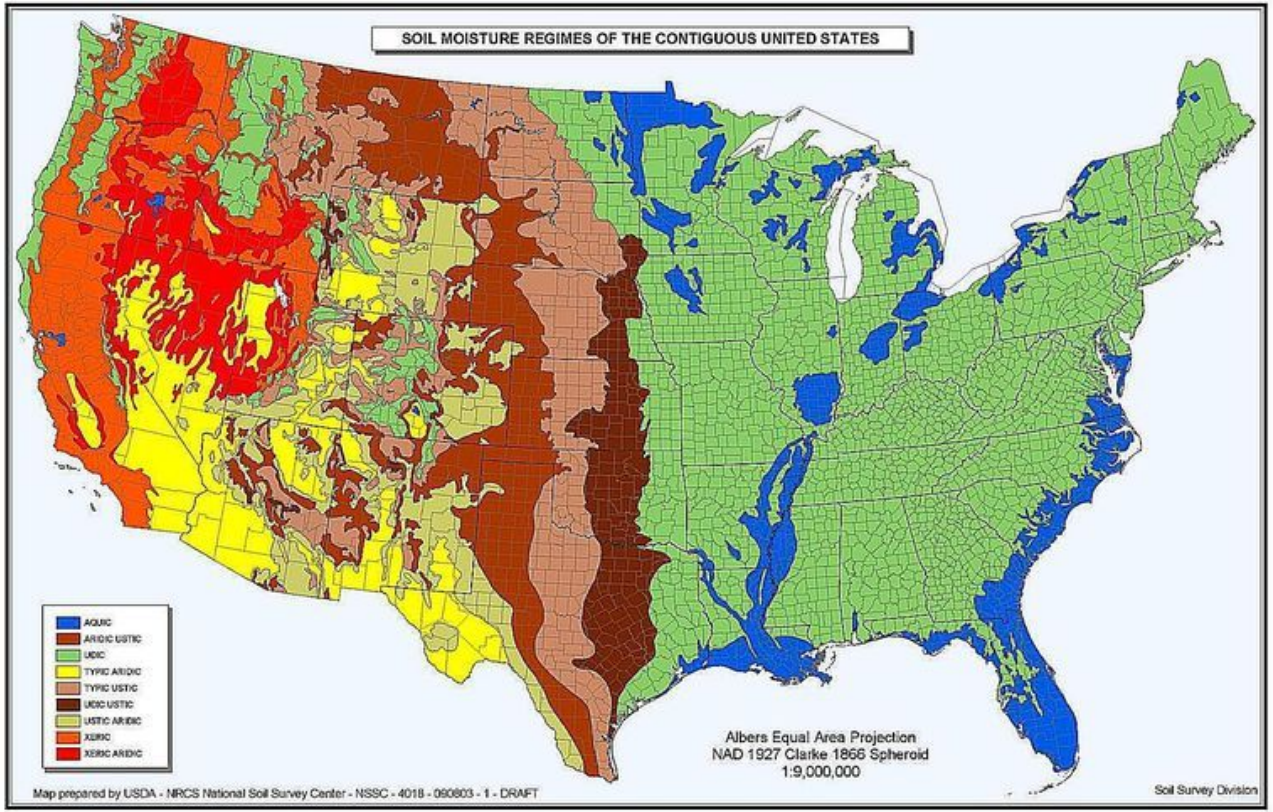
Thematic Maps

- A map with a theme

Thematic Maps

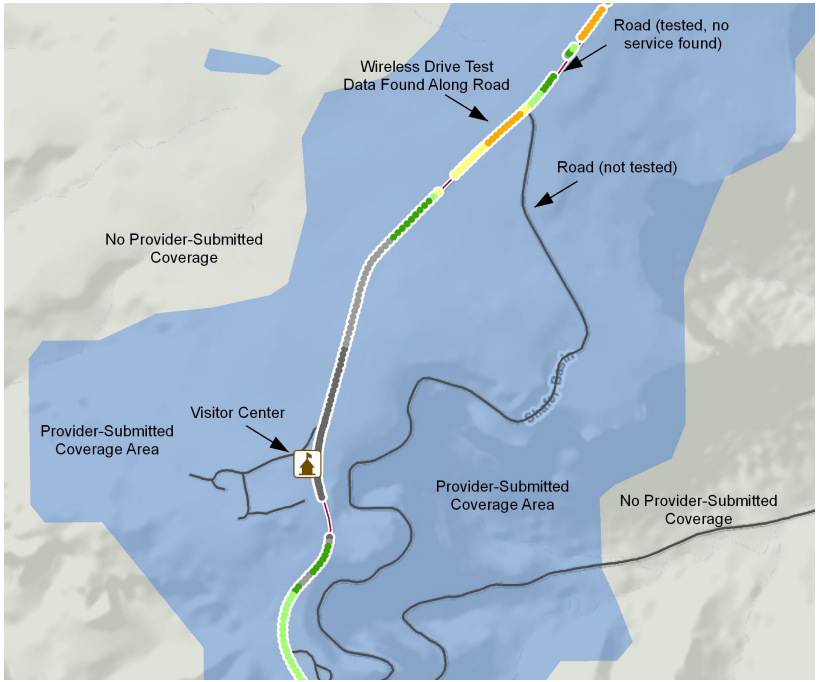
- A map with a theme
- The theme is *there*, but would not be seen from above

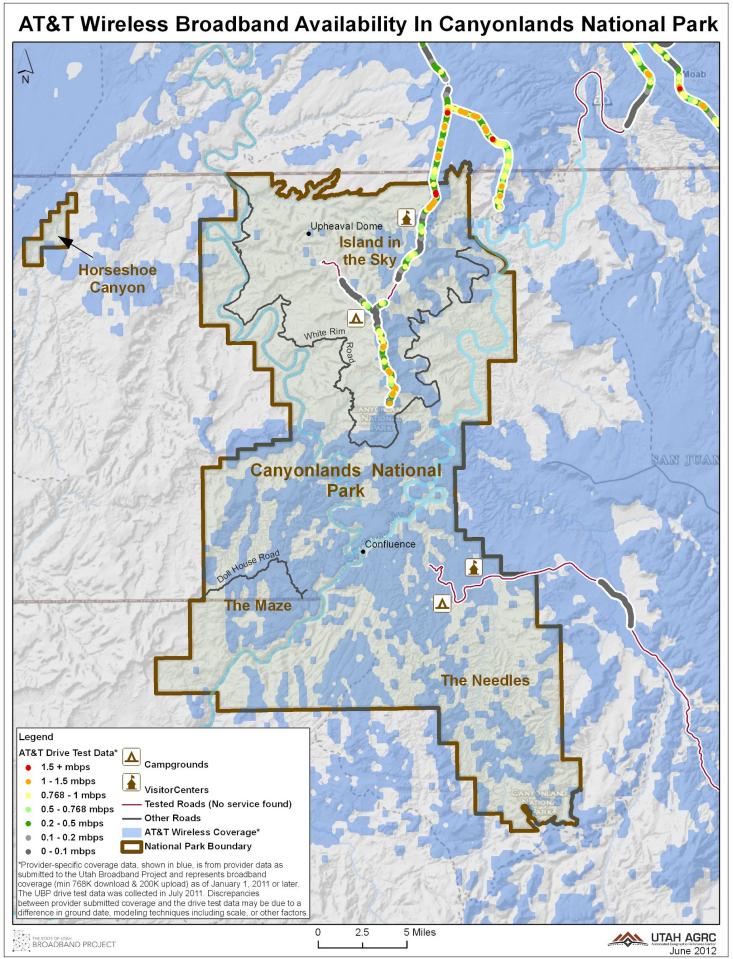
Thematic Maps



https://www.thoughtco.com/thematic-maps-overview-1435692

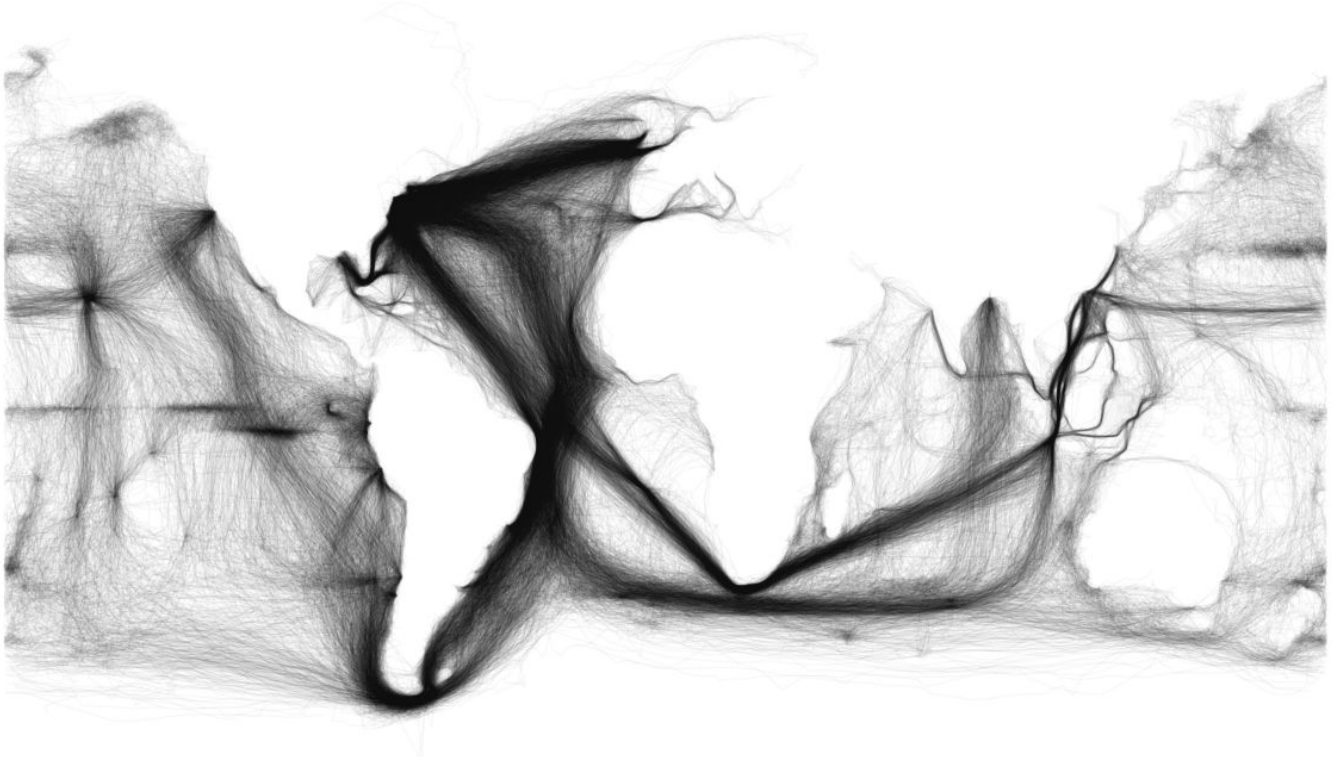
Thematic Maps





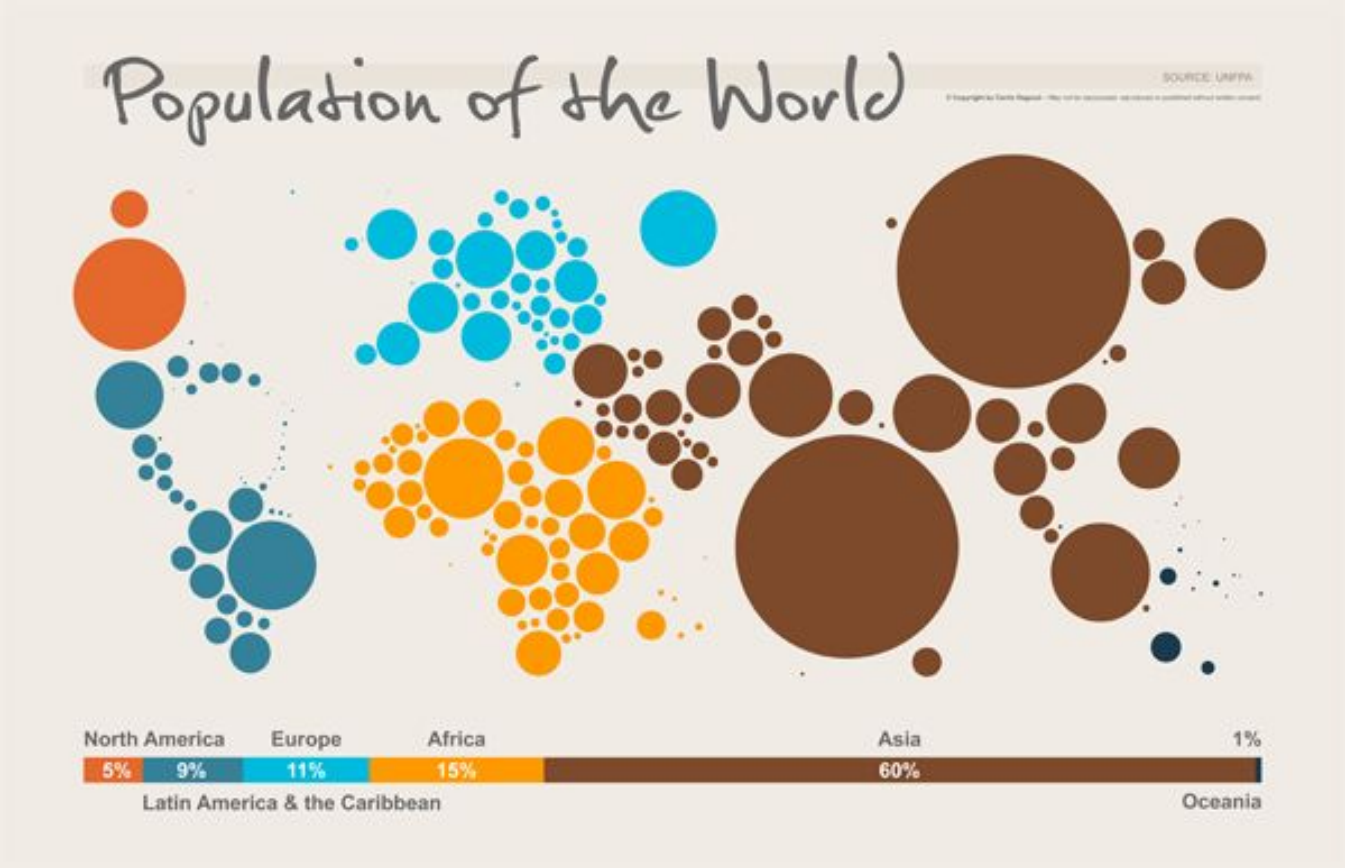
https://broadband.utah.gov/wp-content/uploads/2013/02/zion1.pdf

Thematic Maps



http://sappingattention.blogspot.com/2012/11/reading-digital-sources-case-study-in.html

Thematic Maps



https://mir-s3-cdn-cf.behance.net/project_modules/disp/5127ee21354761.560441ee3d21a.png

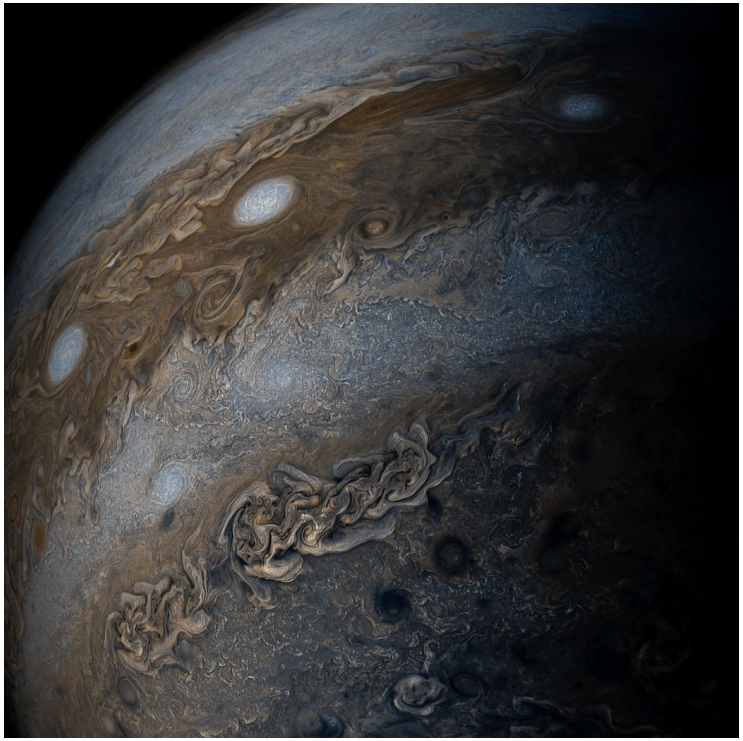
Thematic Maps

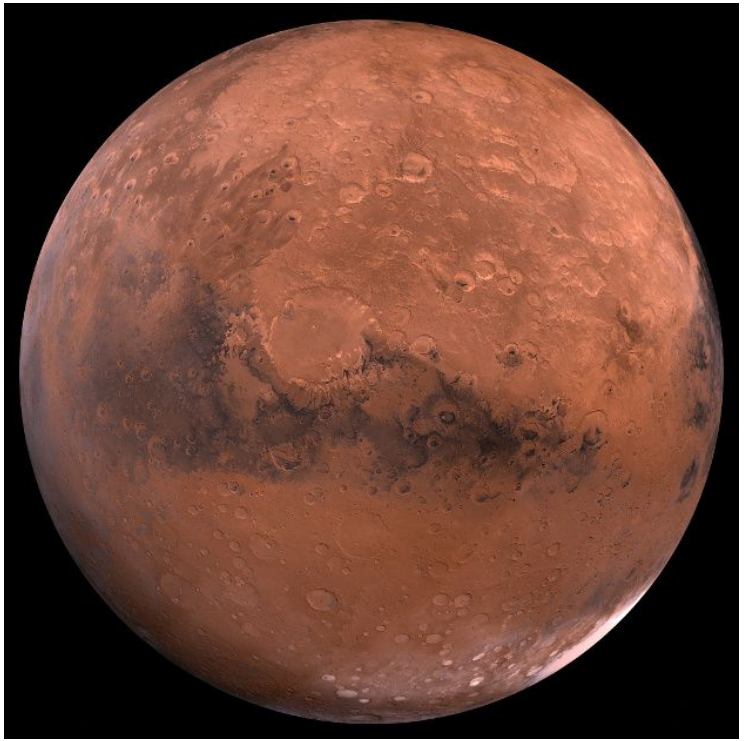
- Infinite themes to be mapped and spatial questions to ask

Thematic Maps

- Infinite themes to be mapped and spatial questions to ask
- We make maps with GIS

Non-Earth Maps





https://www.nasa.gov/image-feature/jpl/pia21334/saturnian-dawn
http://space-facts.com/wp-content/uploads/mars.jpg

Non-Earth Maps

http://ksassets.timeincuk.net/wp/uploads/sites/55/2017/07/Game-of-Thrones-opening-sequence-Winterfell-920x584.jpg
https://www.polygon.com/2016/7/4/12093570/game-of-thrones-map-westeros

Non-Earth Maps

https://vignette3.wikia.nocookie.net/lotr/images/7/72/Middleearthmap.jpg/revision/latest?cb=20100402045252

What is GIS?

What is GIS?

- A system that allows you to visualize, question, analyze, and interpret data to understand spatial relationships, patterns, and trends.

What is GIS?

- A system that allows you to visualize, question, analyze, and interpret data to understand spatial relationships, patterns, and trends.
- GIS is widely used in organizations of all sizes and in almost every industry.

What is GIS?

- A system that allows you to visualize, question, analyze, and interpret data to understand spatial relationships, patterns, and trends.
- GIS is widely used in organizations of all sizes and in almost every industry.
- A mix of data, science, analysis, and maps.

We Use GIS to Answer *Where* Questions

We Use GIS to Answer *Where* Questions

- Where is the zoo and how do we get there?

We Use GIS to Answer *Where* Questions

- Where is the zoo and how do we get there?
- Where are traffic conditions best right now?

We Use GIS to Answer *Where* Questions

- Where is the zoo and how do we get there?
- Where are traffic conditions best right now?
- Where will I be able to go to see the solar eclipse?

We Use GIS to Answer *Where* Questions

- Where is the zoo and how do we get there?
- Where are traffic conditions best right now?
- Where will I be able to go to see the solar eclipse?
- Where should we build a store/wind turbine/solar panel?

We Use GIS to Answer *Where* Questions

- Where is the zoo and how do we get there?
- Where are traffic conditions best right now?
- Where will I be able to go to see the solar eclipse?
- Where should we build a store/wind turbine/solar panel?
- Where would nitrogen and phosphorus runoff be affected if there are changes in infrastructure?

We Use GIS to Answer *Where* Questions

- Where is the zoo and how do we get there?
- Where are traffic conditions best right now?
- Where will I be able to go to see the solar eclipse?
- Where should we build a store/wind turbine/solar panel?
- Where would nitrogen and phosphorus runoff be affected if there are changes in infrastructure?
- Where will the hurricane hit and what cities will be impacted?

We Use GIS to Answer *Where* Questions

- Where is the zoo and how do we get there?
- Where are traffic conditions best right now?
- Where will I be able to go to see the solar eclipse?
- Where should we build a store/wind turbine/solar panel?
- Where would nitrogen and phosphorus runoff be affected if there are changes in infrastructure?
- Where will the hurricane hit and what cities will be impacted?
- Where should we place advertisements so that people see them who are most likely to buy our product?

We Use GIS to Answer *Where* Questions

- Where is the zoo and how do we get there?
- Where are traffic conditions best right now?
- Where will I be able to go to see the solar eclipse?
- Where should we build a store/wind turbine/solar panel?
- Where would nitrogen and phosphorus runoff be affected if there are changes in infrastructure?
- Where will the hurricane hit and what cities will be impacted?
- Where should we place advertisements so that people see them who are most likely to buy our product?
- ...

What Makes Up a GIS?

G

I

S

What Makes Up a GIS?

Geographic

Information

System

What Makes Up a GIS?

Geographic - Spatial

Information

System

What Makes Up a GIS?

Geographic - Spatial

Information - Attributes

System

What Makes Up a GIS?

Geographic - Spatial

Information - Attributes

System - All the moving parts

What Makes Up a GIS?

Geographic - Spatial

Information - Attributes

System - All the moving parts

A system that allows you to store, process, and visualize information with a spatial component.

What Makes Up a GIS?

- People
- Methods
- Data
- Software
- Hardware

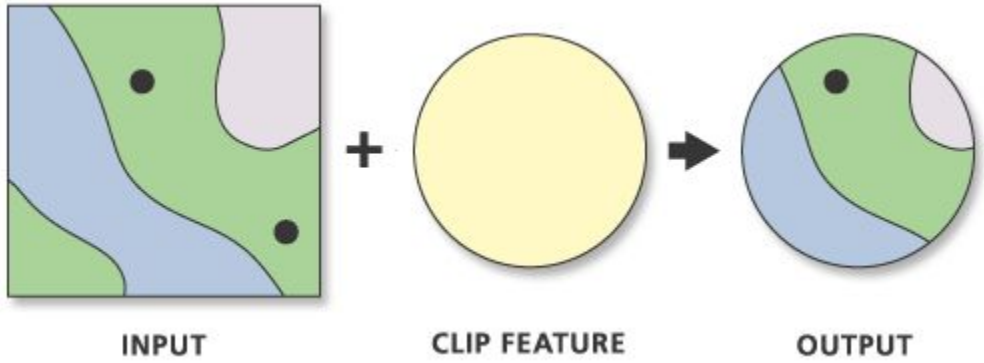
https://previews.123rf.com/images/naschy/naschy1611/naschy161100009/67318622-Vector-Illustration-of-GIS-Spatial-Data-Layers-Con
t-for-Business-Analysis-Geographic-Information--Stock-Vector.jpg

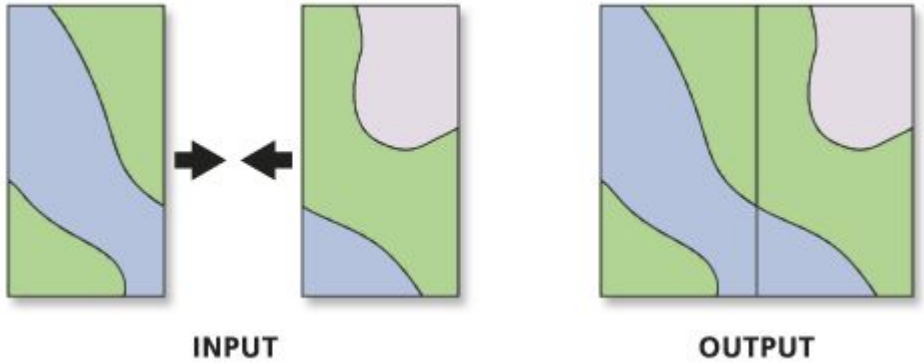
5. People

- Users and creators of the GIS
- Asking questions
- Designing methods
- Making maps
- Sharing/Deploying maps and mapping applications

4. Analysis/Methods

- Buffer
- Clip
- Transform

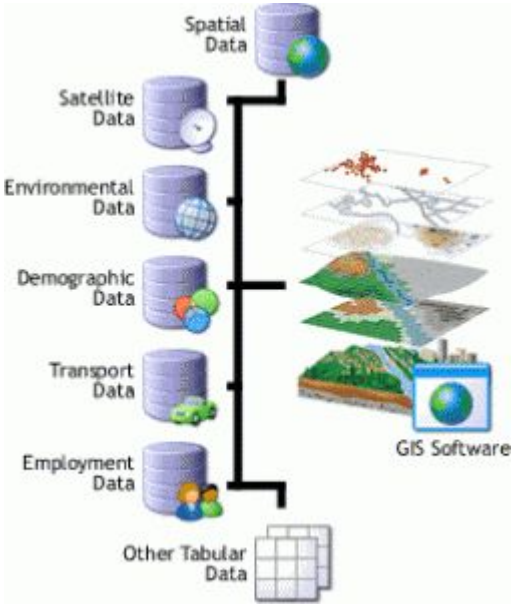




http://pro.arcgis.com/en/pro-app/tool-reference/data-management/GUID-AF3DF698-56D0-4BE3-946D-0089F91EC1A3-web.png

3. Data

- Files/Database
- Spatial characteristics
- Multiple sources



http://www.whatisgis.com/wp-content/uploads/2012/06/gis_dbSoftware-253x300.gif

2. Software

- Operating System
- Mapping Application

MapInfo®
THE INFORMATION DISCOVERY COMPANY

ArcGIS
ESRI

QGIS®
Trademark

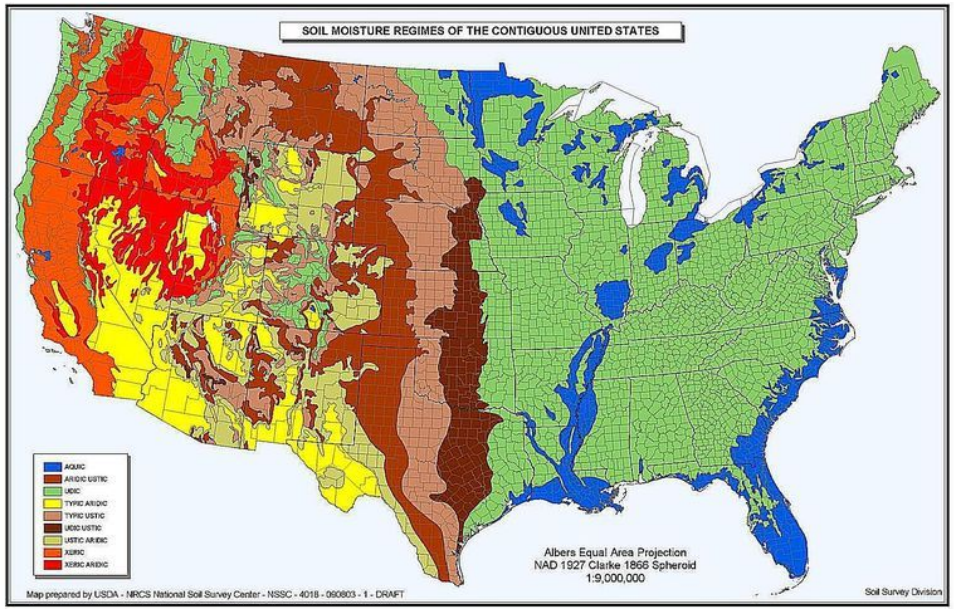
1. Hardware

- Computers/Servers
- Scanner
- Plotter
- GPS Unit

https://mind42.com/public/7281a3b5-0cc5-462c-bc92-5d53439e6b57

Maps

- The way we display GIS data



https://www.thoughtco.com/thematic-maps-overview-1435692

Web Maps

- Base Maps
- Thematic Layers
- Interactive/Dynamic Map elements
- Tiles (raster and vector)
- Caching
- Live Data Sources
- Web Services

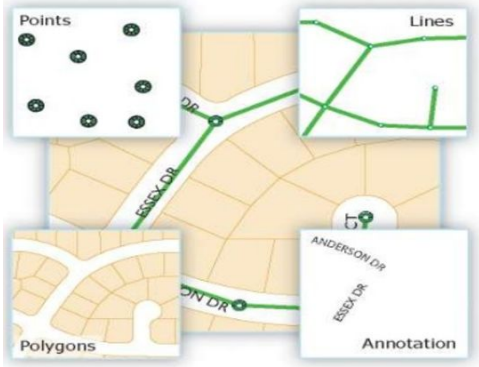
What Makes GIS Data Different?

- Things to Consider

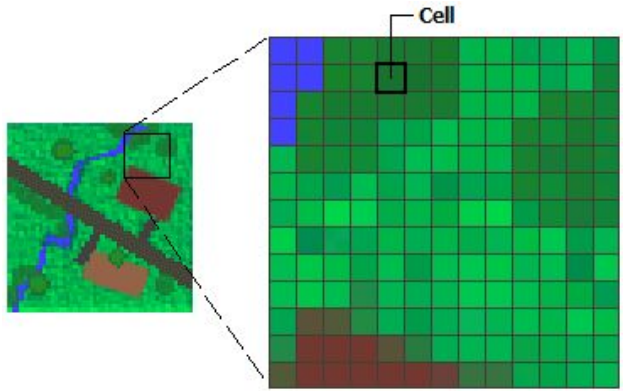
http://www.pngall.com/wp-content/uploads/2016/06/Earth-PNG-Pic.png

Vector/Raster

- Vector - discrete entities: points, lines, and polygons

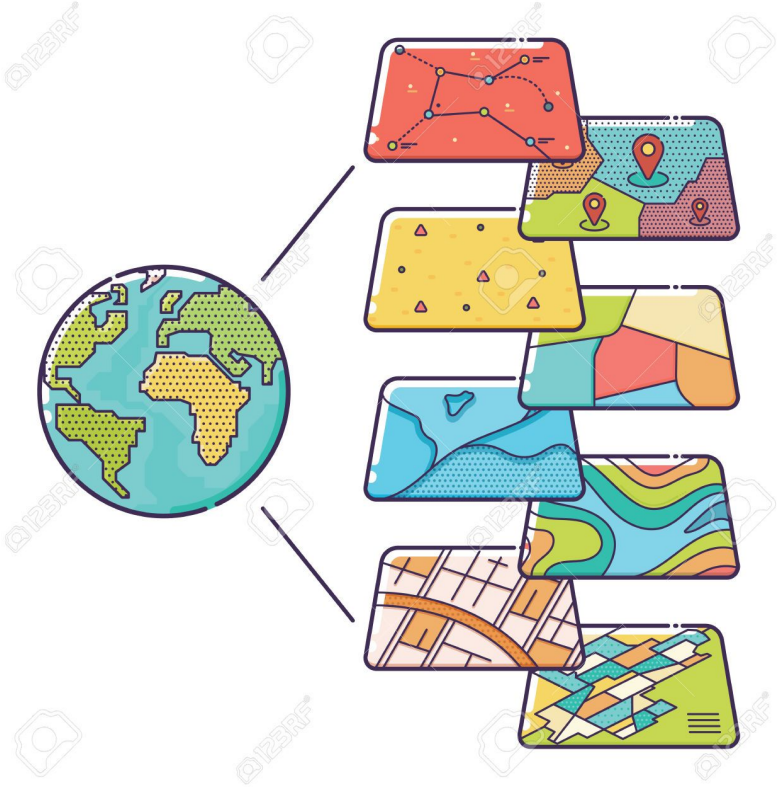


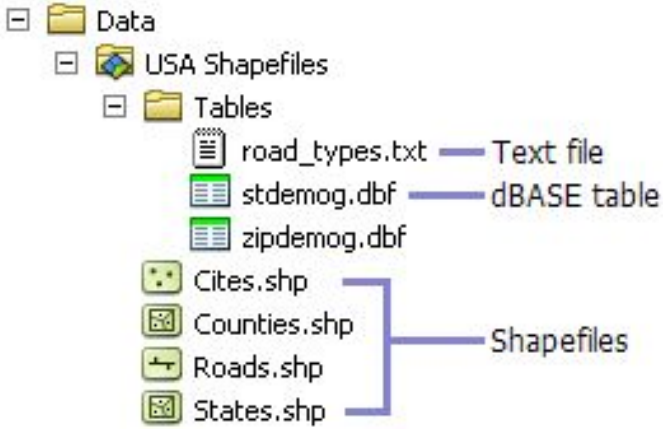
- Raster - images consisting of regularly sized and spaced cells where every cell has a value



https://image.slidesharecdn.com/introductiontogis-151109064609-lva1-app6891/95/introduction-to-gis-15-638.jpg?cb=1447383776
http://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/GUID-6754AF39-CDE9-4F9D-8C3A-D59D93059BDD-web.png

Vector





https://previews.123rf.com/images/naschy/naschy1611/naschy161100009/67318622-Vector-Illustration-of-GIS-Spatial-Data-Layers-Co
ept-for-Business-Analysis-Geographic-Information--Stock-Vector.jpg
tp://desktop.arcgis.com/en/arcmap/10.3/manage-data/shapefiles/GUID-AFEE52B3-BBE8-4F33-A55B-5CFD5106B80C-web.png

Vector

states :: Features total: 51, filtered: 51, ...

	;TATE_NAM	DRAWSEQ	STATE_FIPS	;UB_REGION	;TATE_ABBR
24	Utah	24	49	Mountain	UT
25	California	25	06	Pacific	CA
26	Ohio	26	39	East North ...	OH
27	Illinois	27	17	East North ...	IL
28	District of ...	28	11	South Atla...	DC
29	Delaware	29	10	South Atla...	DE
30	West Virginia	30	54	South Atla...	WV

Show All Features

Raster

- Digital Elevation Model
- One elevation value per cell

http://igic.org/news/media/5/elevation.jpg

Raster

- National Landcover Database
- One land cover designation per cell

https://www.mrlc.gov/nlcd06_data.php

Raster

Water

11 Open Water
12 Perennial Ice/Snow

Developed

21 Low Intensity Residential
22 High Intensity Residential
23 Commercial/Industrial/Transportation

Barren

31 Bare Rock/Sand/Clay
32 Quarries/Strip Mines/Gravel Pits
33 Transitional

Forested Upland

41 Deciduous Forest
42 Evergreen Forest
43 Mixed Forest

Shrubland

51 Shrubland

Non-Natural Woody

61 Orchards/Vineyards/Other

Herbaceous Upland Natural/Semi-natural Vegetation

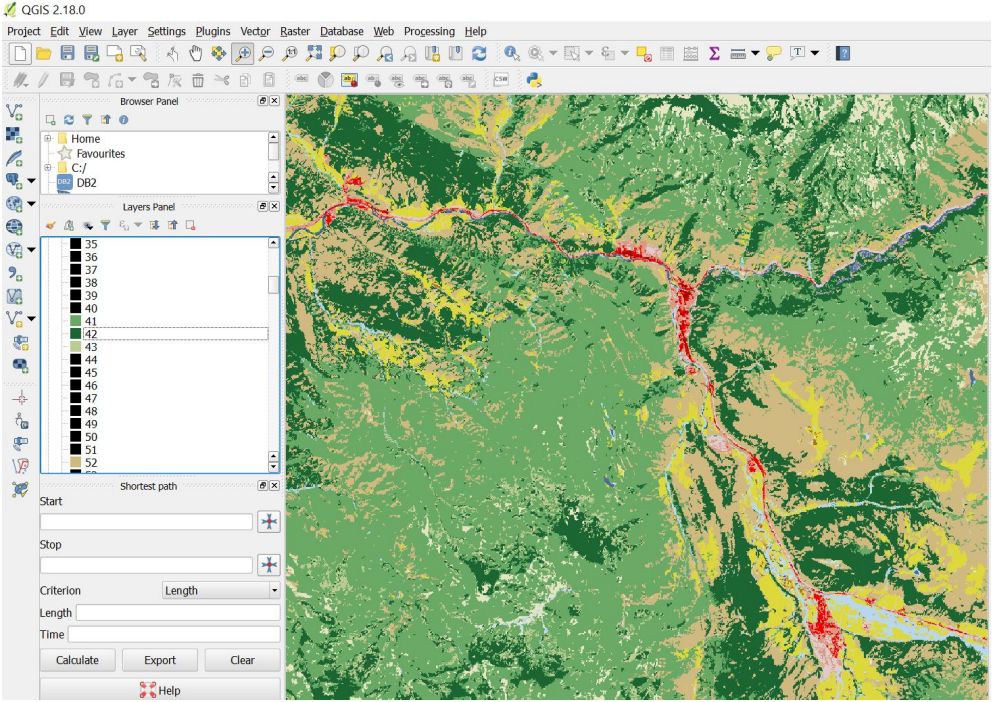
71 Grasslands/Herbaceous

Herbaceous Planted/Cultivated

81 Pasture/Hay
82 Row Crops
83 Small Grains
84 Fallow
85 Urban/Recreational Grasses

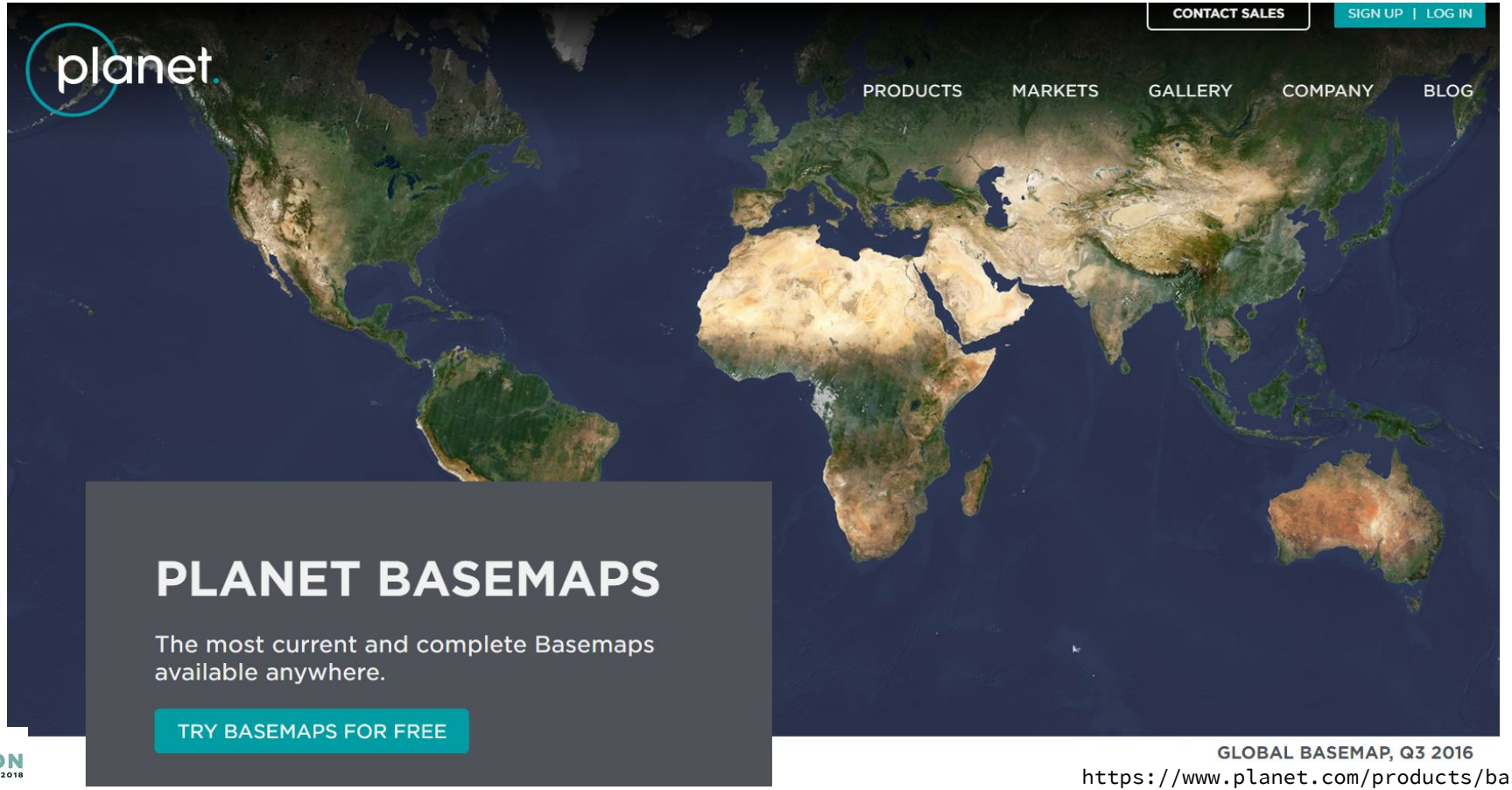
Wetlands

91 Woody Wetlands
92 Emergent Herbaceous Wetlands



https://landcover.usgs.gov/classes.php

Aerial Imagery



Data Acquisition

- Not all data exists
- May be costly or difficult
- Lots of data is available

OpenStreetMap

United States™ Census Bureau

bing

Common Data Sources

- Government
- Census
- Crowd sourced
- Proprietary

OpenStreetMap

United States™ Census Bureau

bing

Data Quality

- Know your source
- Trust your source
- Cite your source

OpenStreetMap

United States™ Census Bureau

bing

Scale

- How many inches represent 1 mile?
- How much information do you show?
- At what scales?

Remember Base Maps

1:7,500,000

1:15,000

Esri, 2018

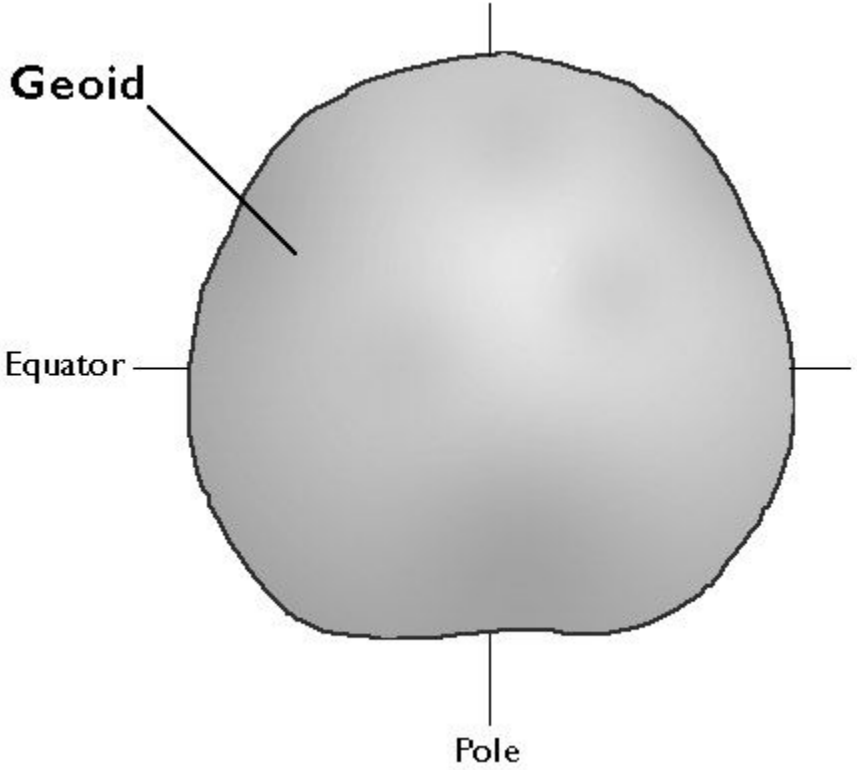
Data Collection and GPS

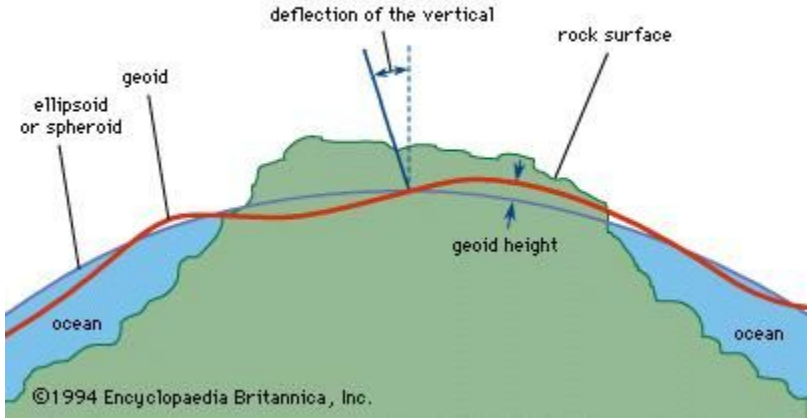
http://www.figonet.com/wp-content/uploads/2013/12/science-of-gps.jpg

The Earth is Not Flat

http://www.pngall.com/wp-content/uploads/2016/06/Earth-PNG-Pic.png

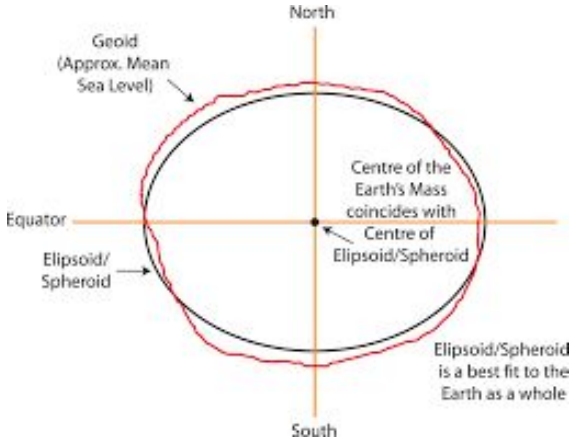
Geoid





ttps://www.e-education.psu.edu/natureofgeoinfo/sites/www.e-education.psu.edu.natureofgeoinfo/files/image/geoid_diagram.jpg
ttps://media1.britannica.com/eb-media/67/467-004-E3A4C9EC.jpg

Ellipsoid



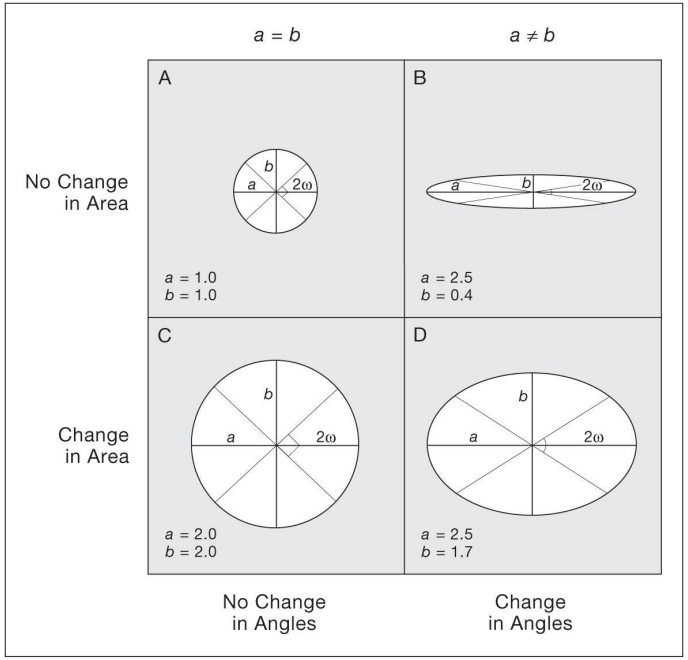
http://www.icsm.gov.au/mapping/datums1.html

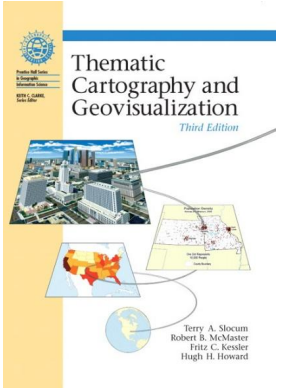
Projections

http://www.statcan.gc.ca/pub/92-195-x/2011001/other-autre/mapproj-projcarte/images/m-c.jpg

Projection Distortion

- Area
- Angles
- Shape
- Distance
- Direction



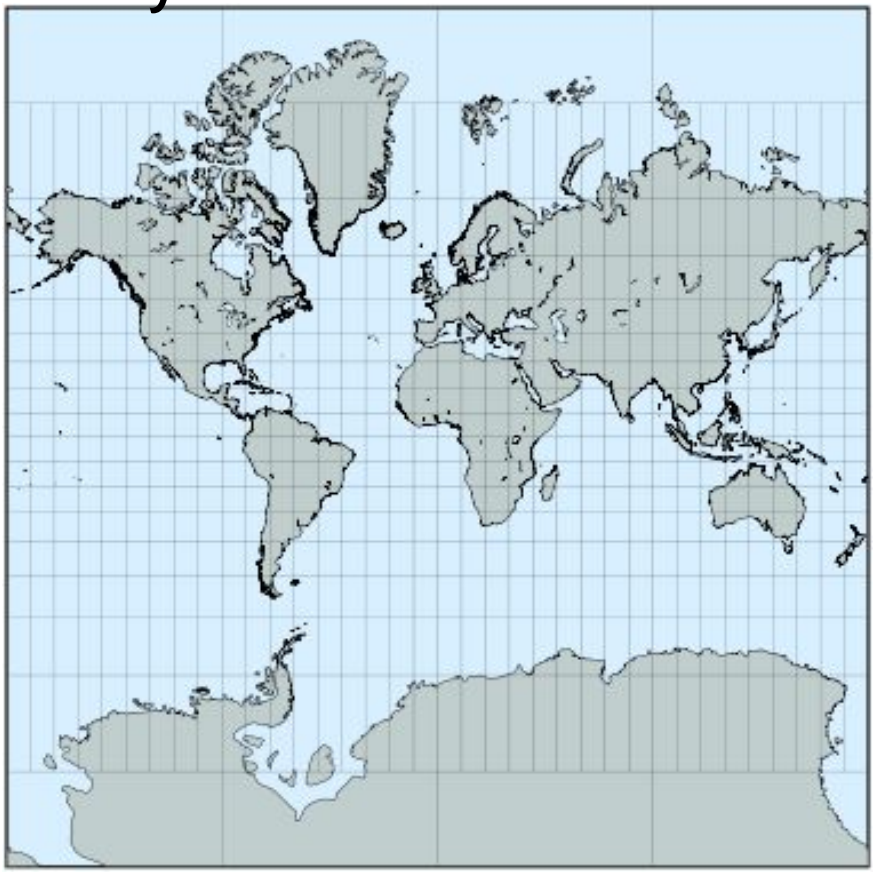


Slocum, Terry A., Robert B. McMaster, Fritz C. Kessler, and Hugh H. Howard. 2009. *Thematic Cartography and Geovisualization. 3rd Edition.* Upper Saddle River, NJ: Pearson Prentice Hall.

Projections

The World Mercator Projection EPSG:3395

- Straight lines across oceans made for sea navigation
- Used in web maps
- Distorted at the poles



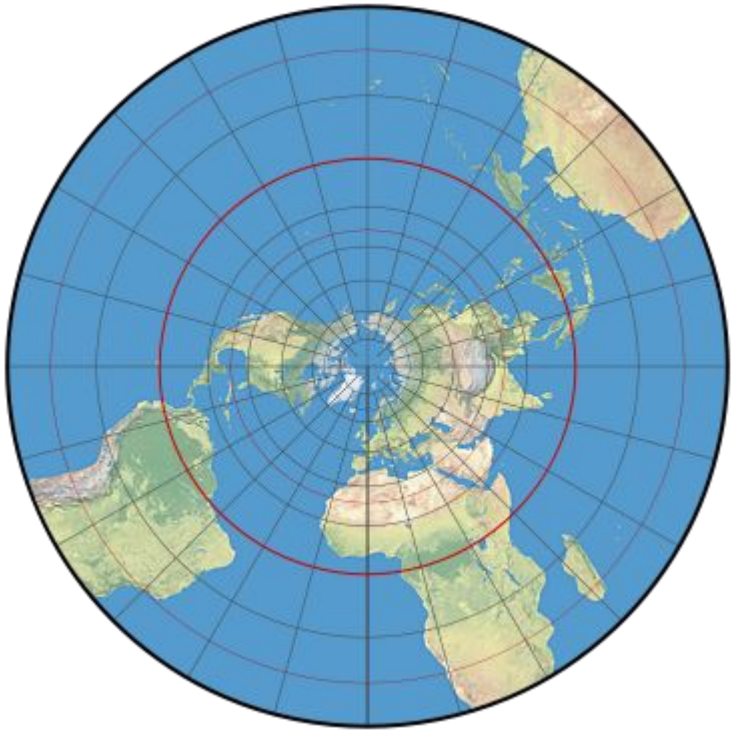
http://www.progonos.com/furuti/MapProj/Normal/ProjNav/Img/mp_Mercator-s60.png

The World Mercator Projection
EPSG:3395

maps.google.com

The Polar Stereographic Projection EPSG:3995

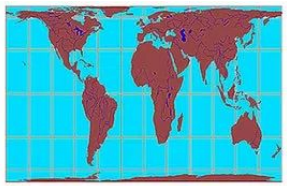
- Only the center is true to scale



https://www.mapthematics.com/ProjectionsList/Projectioninfo/stereographic-map.png

Other Map Projections

Mercator Projection



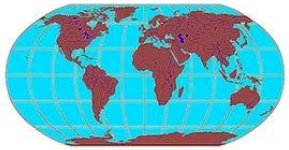
Gall-Peters Projection

Miller Cylindrical Projection

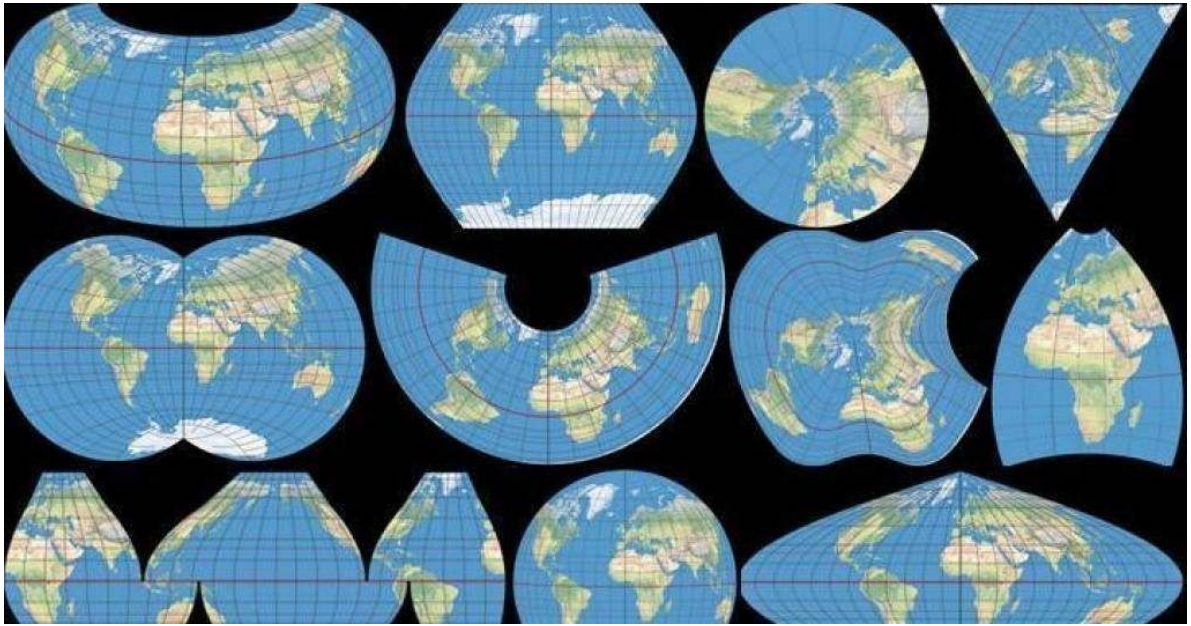
Mollweide Projection

Goode's Homolosine Equal-area Projection

Sinusoidal Equal-Area Projection

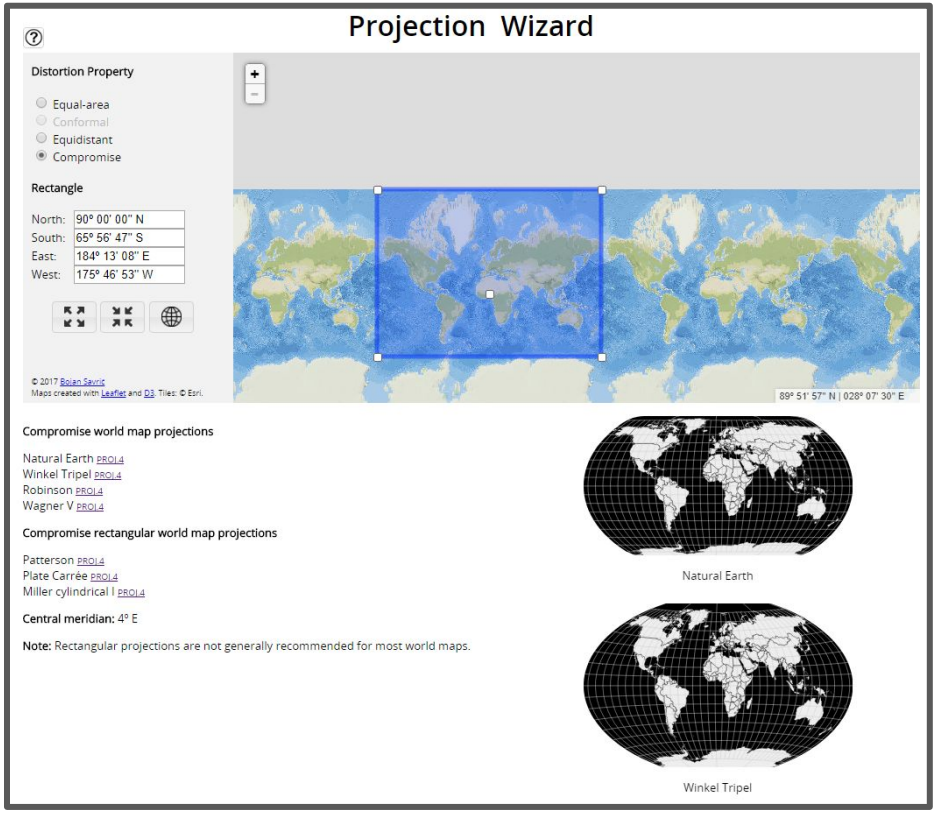


Robinson Projection



http://ahasanulhoque.com/wp-content/uploads/2017/04/map-projections-u1-1024x537-1024x537.jpg
https://i2.wp.com/geoawesomeness.com/wp-content/uploads/2013/09/projections.jpg

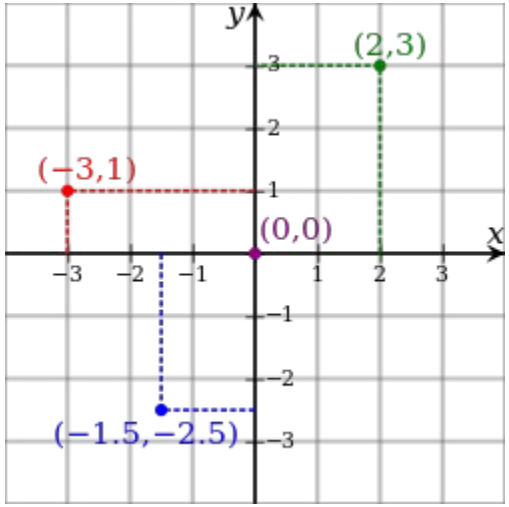
Map Projection Tools



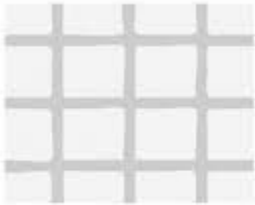
http://projectionwizard.org/

Coordinate Systems

- How we define a location
- Geographic/Unprojected
- Projected



Geographic (3D)

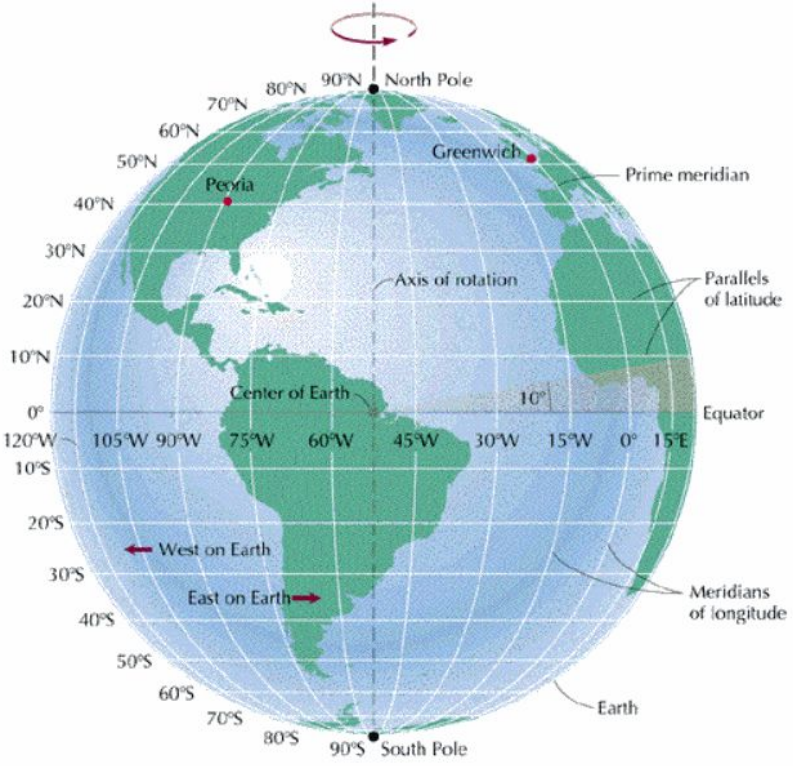


Projected (2D)

https://upload.wikimedia.org/wikipedia/commons/thumb/0/0e/Cartesian-coordinate-system.svg/250px-Cartesian-coordinate-system.svg.png
https://static1.squarespace.com/static/55bb8935e4b046642e9d3fa7/55bb8e8ee4b03fcc125a74c0/55bb8e91e4b03fcc125a7a66/1326905027513/1000w/coordinate_systems.jpg

WGS84 Geographic/Unprojected Coordinate System

- Latitude, Longitude
- Used by GPS to express locations on the earth, and GeoJSON
- EPSG:4326

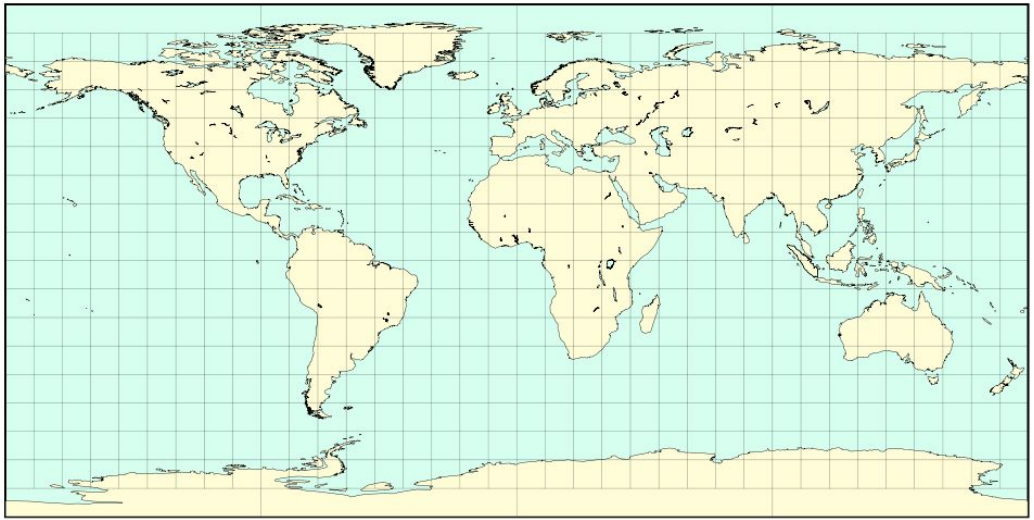


Cleveland, OH
41.4993° N, 81.6944° W

http://www.mymanatee.org/.imaging/stk/mcg-mymanatee/zoom/dms/departments/information-services/gis/gis-stage-images/EarthLatLong/document/EarthLatLong.gif

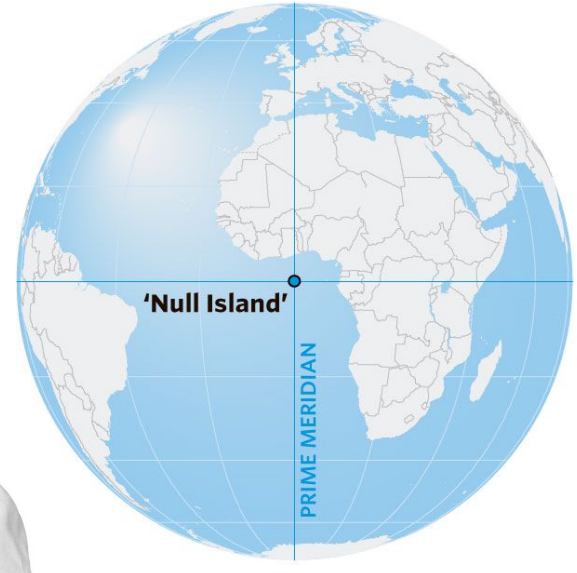
WGS84 Geographic/Unprojected Coordinate System

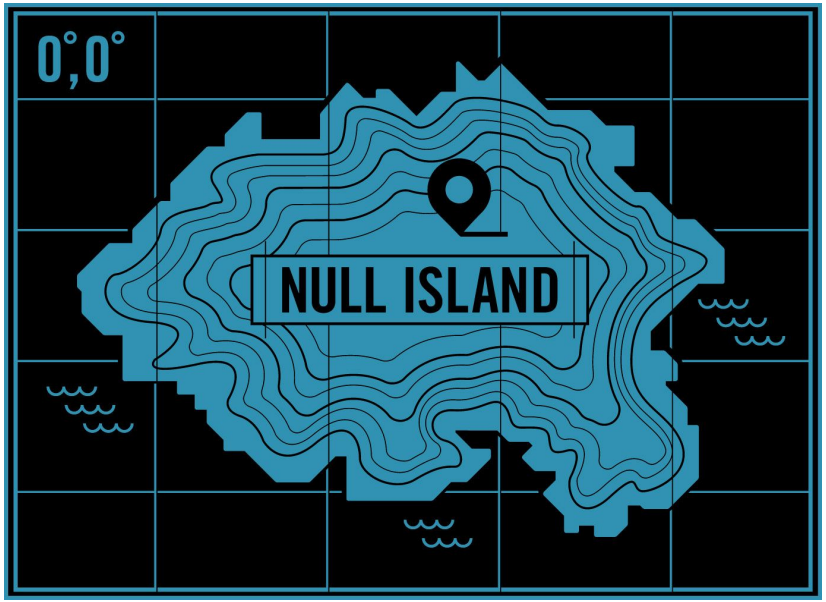
Usually projected in Plate-Carrée, which creates a linear Cartesian graph on the page



http://www.mymanatee.org/.imaging/stk/mcg-mymanatee/zoom/dms/departments/information-services/gis/gis-stage-images/EarthLatLong/document/EarthLatLong.gif

WGS84 Geographic/Unprojected Coordinate System

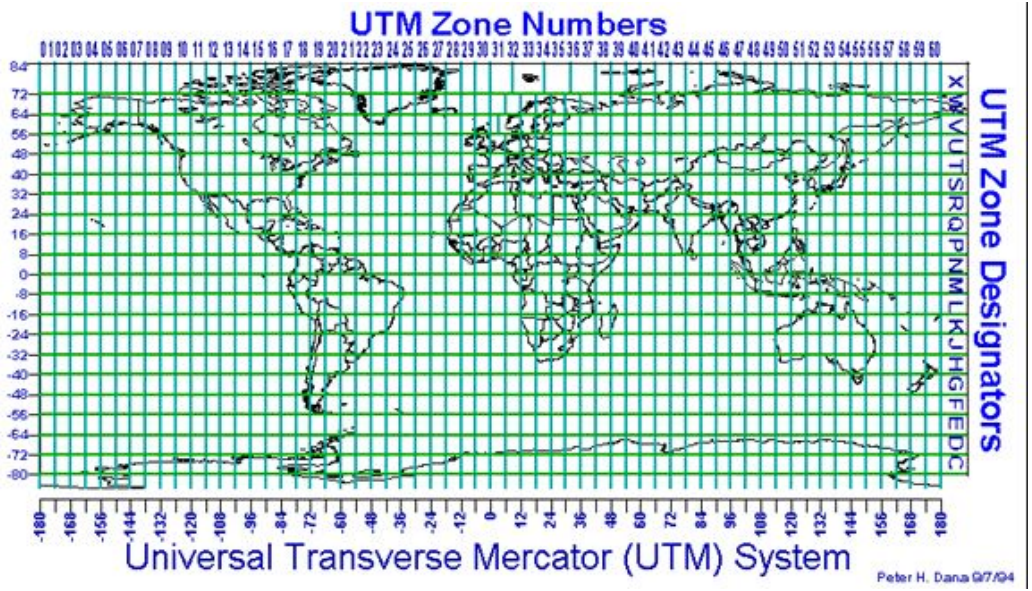




https://www.vicchi.org/wp-content/uploads/2014/04/null_island.jpg
https://si.wsj.net/public/resources/images/BN-OW822_backgr_1_20160713091316.jpg

The Universal Transverse Mercator Coordinate System

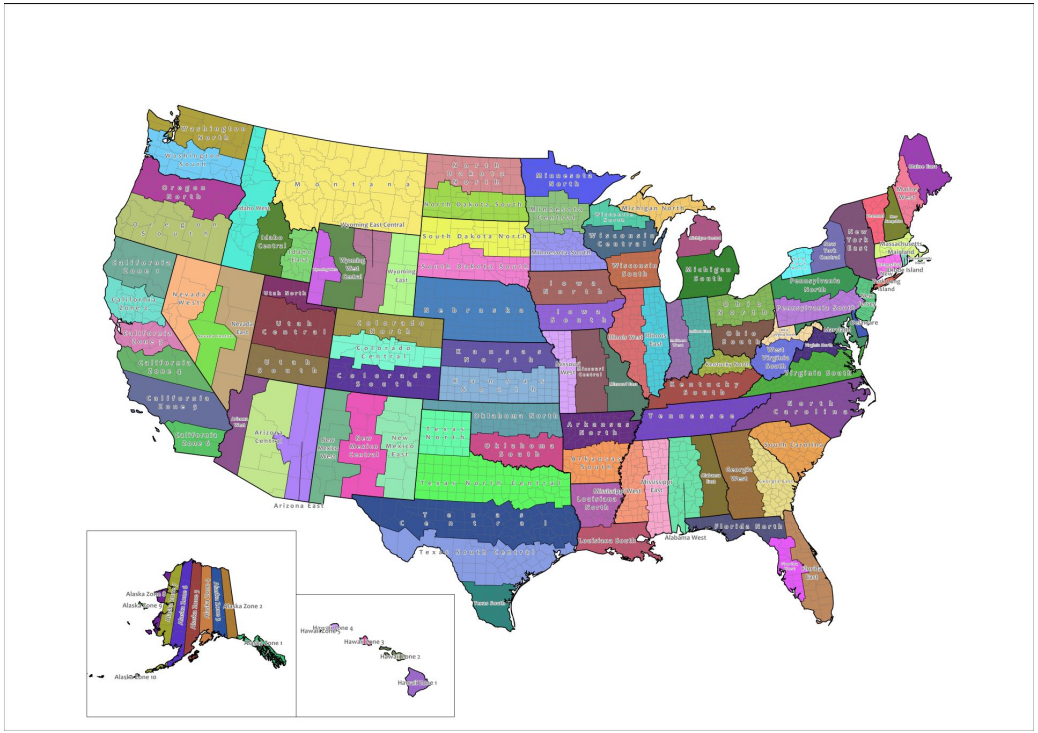
- Separated into 60 zones
- Uses a transverse mercator projection



http://gis.depaul.edu/shwang/teaching/geo381/LN4_files/image039.gif

The State Plane Coordinate System

- Optimized for states and zones
- Projections vary



http://www.edc.uri.edu/nrs/classes/nrs409509/Lectures/4MapBasics/SPZones.png

Maps Caveats

- All models are wrong
- Depending on the projection:
  - Sizes are not consistent
  - Lines are not straight lines
  - Areas are distorted
- Data issues after processing
- Maps can be used to intentionally mislead
- Even a very good model is a simplification

This is Not How the World Looks

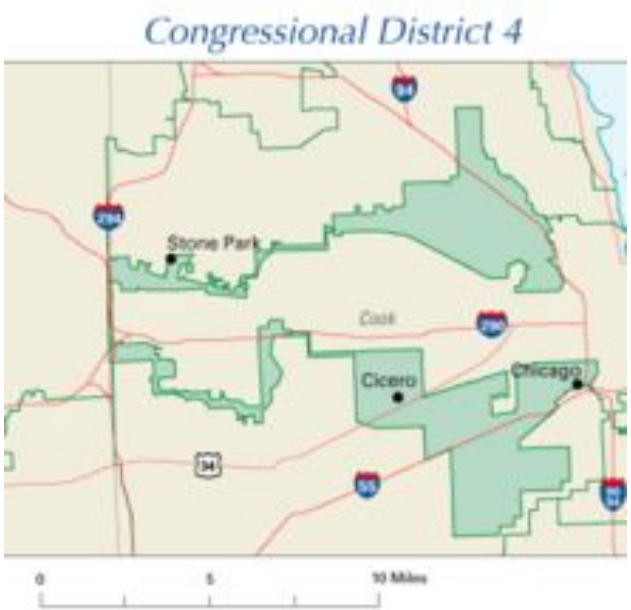
GLOBAL BASEMAP, Q3 2016

https://www.planet.com/products/basemap

Maps Can Be Used to Mislead

Monkey Cage • Analysis

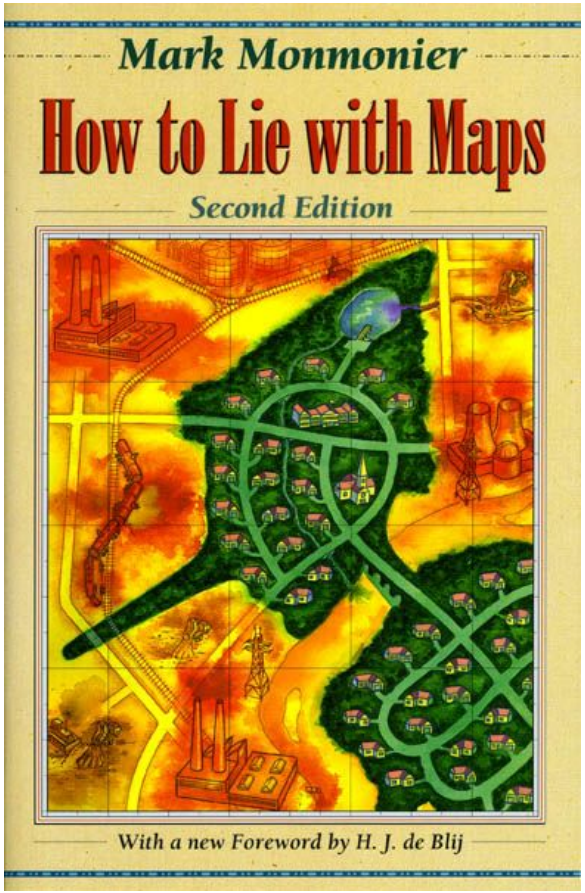
The Supreme Court will examine partisan gerrymandering in 2017. That could change the voting map.



https://www.washingtonpost.com/news/monkey-cage/wp/2017/01/31/the-supreme-court-will-examine-partisan-gerrymandering-in-2017-that-could-change-the-voting-map/?utm_term=.6455d75cd19f
https://upload.wikimedia.org/wikipedia/commons/9/99/Illinois_District_4_2004.png

Maps Can Be Used to Mislead

"How to Lie with Maps"



http://tmm.chicagodistributioncenter.com/IsbnImages/9780226534213.jpg

Maps Can Be Used to Mislead

Choice of colors, color classifications, data, and aggregation units can make maps tell different stories

Use GIS

- Understand our world
- Answer spatial questions
- Make beautiful visualizations

https://www.greatamericaneclipse.com/best-places-to-view

To Sum Up...

To Sum Up...

- Maps are great visualizations

To Sum Up...

- Maps are great visualizations
- There’s a lot that goes into GIS

To Sum Up...

- Maps are great visualizations
- There’s a lot that goes into GIS
- Spatial data is different

To Sum Up...

- Maps are great visualizations
- There’s a lot that goes into GIS
- Spatial data is different
- Think critically when using maps

To Sum Up...

- Maps are great visualizations
- There’s a lot that goes into GIS
- Spatial data is different
- Think critically when using maps
- Use GIS to solve problems and make maps!

python

- General purpose programming language
- Free and open source
- Has a wide variety of uses such as building applications, websites, statistics, calculations, data science, etc.

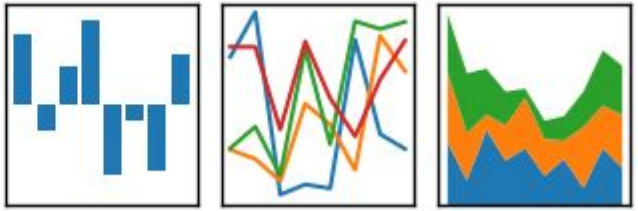
Python for GIS

- Extend the capabilities of mapping applications
- Build a GIS workflow
- Automate redundant tasks
- Integrate maps or spatial data into other applications
- Build your own applications

Python Libraries for GIS

geo pandas

$$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$$



Tools We Will Use Today

- Spatial data
- Python
- Python libraries (Geopandas, etc)
- Conda
- Jupyter Notebook

Geopandas

“GeoPandas is an open source project to make working with geospatial data in Python easier. GeoPandas extends the datatypes used by pandas to allow spatial operations on geometric types. Geometric operations are performed by shapely. Geopandas further depends on fiona for file access and descartes and matplotlib for plotting.”

-http://geopandas.org/

Conda

- Package management system and environment management system
- Tightly coupled with Anaconda and Miniconda

Anaconda and Miniconda

- **Anaconda** - a Python distribution with over 1,000 open sources data science packages and Conda
  - Big - takes a long time to install
  - Creating our environment is faster because there are less dependencies to install
- **Miniconda** - a Python distribution with just Conda and its dependencies
  - Small - quick to install
  - Creating our environment takes longer because there are more dependencies to install

Jupyter Notebook

- An open source web application that allows you to create and share documents that contain live code, equations, visualizations and narrative text.
- Uses include: data cleaning and transformation, numerical simulation, statistical modeling, data visualization, machine learning, and much more. (LIKE MAPPING)

-http://jupyter.org/

Why are we doing it this way?

- Easy to demo a workflow
- Compact and reproducible (used in academia, science)
- Easy to customize and change
- Easy to share your process with non-coders and non-GIS people

Workshop Time!

Go here:

https://github.com/christyheaton/PyCon2018_GISTutorial

Setup instructions are in the README.

Break Time

Base Maps

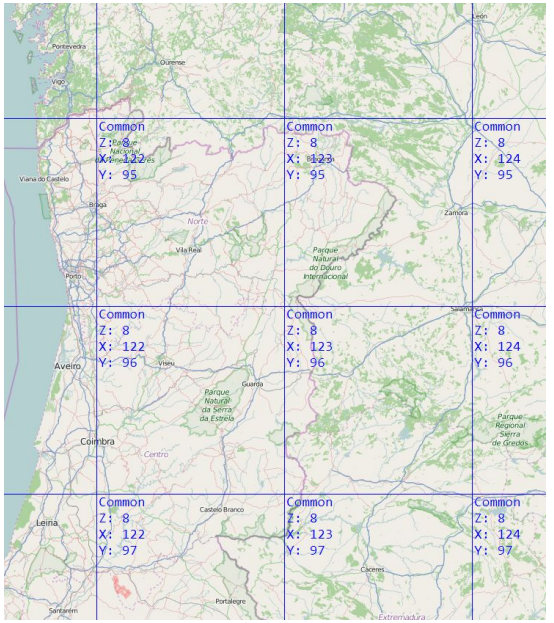
https://www.planet.com/products/basemap

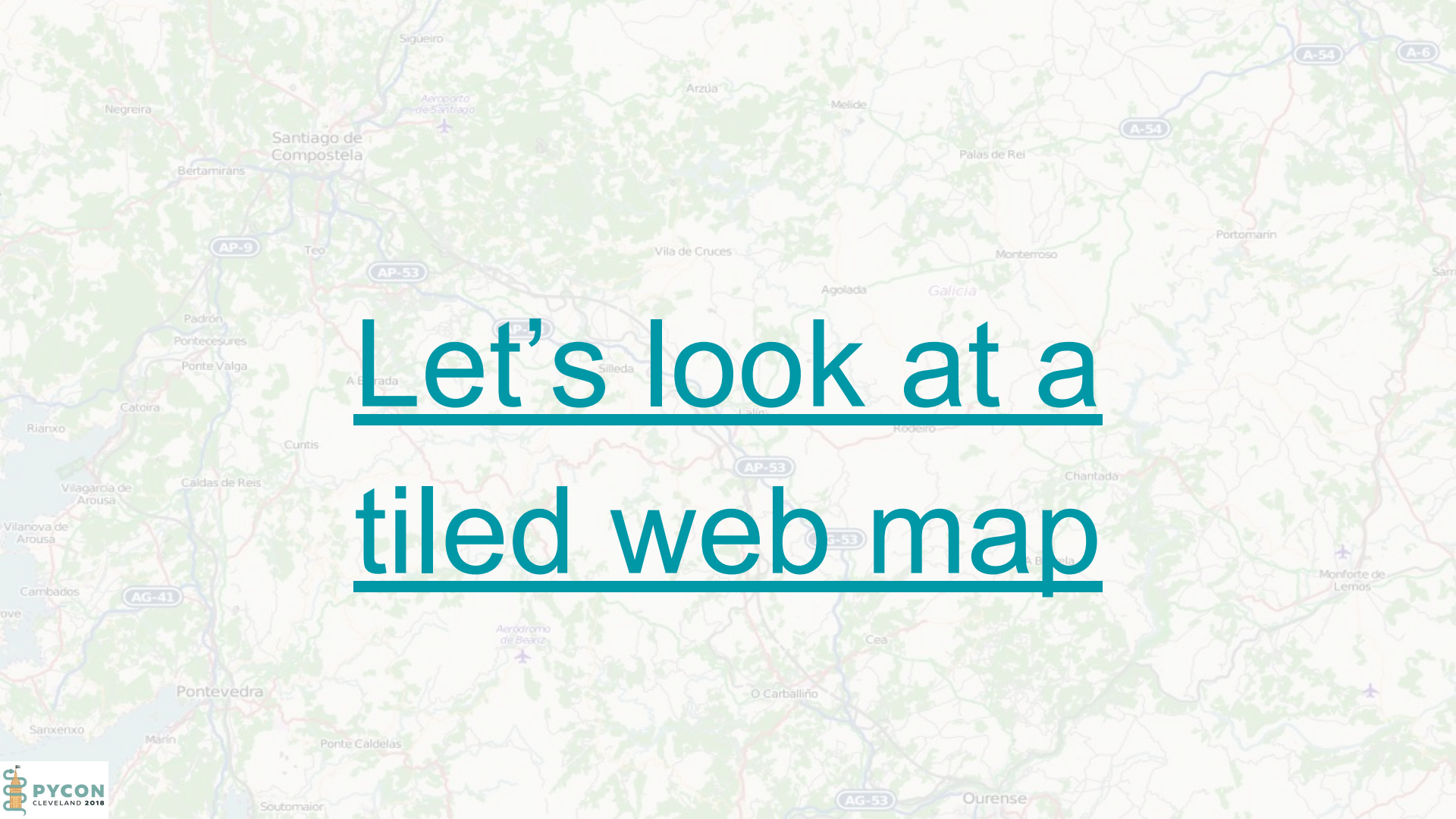
OpenStreetMap (OSM)

- A collaborative project to create a free editable map of the world
- Like Google Maps
- Like Wikipedia

Base Map Tiles

- Usually regularly sized square 256×256 pixel images
- Cover entire map area without gaps or overlap
- Make your own or use existing ones




Let’s look at a tiled web map

Exercise 1: Call OpenStreetMap Tiles

1. Open Chrome developer tools
2. Go to openstreetmap.org or another map site
3. See tile URLs in the developer tools network
4. Copy a tile url and paste it a browser

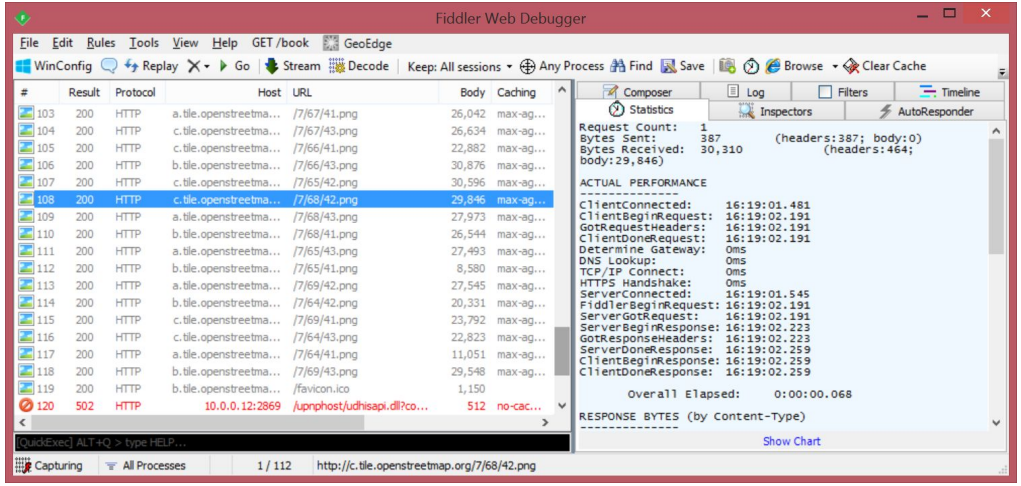
Try a few!

Exercise 1: Call OpenStreetMap Tiles

http://a.tile.openstreetmap.org/5/18/9.png

http://b.tile.openstreetmap.org/7/68/41.png

http://a.tile.openstreetmap.org/7/65/43.png

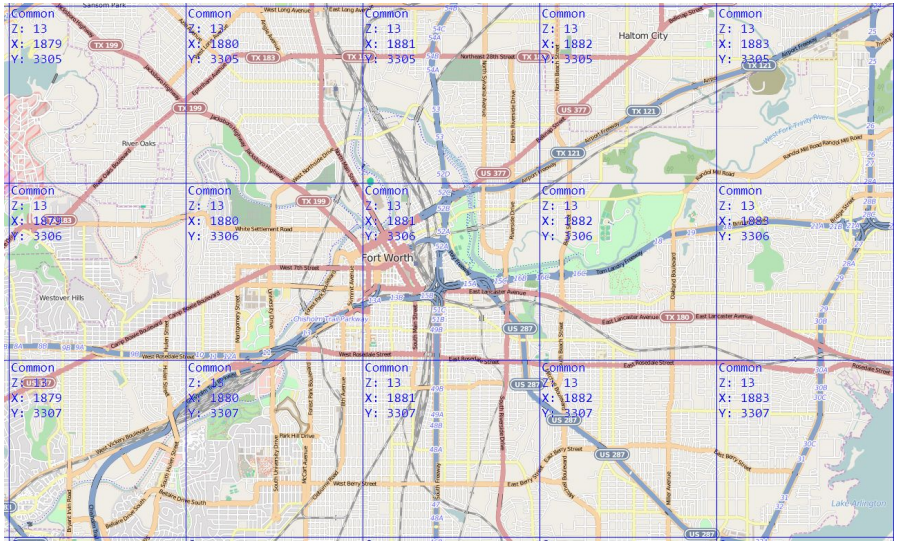


Tile Identification

Z {Level}

X {Column}

Y {Row}



`http://{s}.domain.com/{z}/{x}/{y}.png`

http://tilehelper.azurewebsites.net/

A Web Map Has a Lot of Tiles!

$$\sum_{i=0}^{20} (2^i)^2$$

```
t=0

for i in range(0,21):

    t = t + ((2**i)**2)

print(t)
```

For 20 zoom levels that's...

A Web Map Has a Lot of Tiles!

$$\sum_{i=0}^{20} (2^i)^2$$

```
t=0

for i in range(0,21):

    t = t + ((2**i)**2)

print(t)
```

For 20 zoom levels that's **1,466,015,503,701** tiles!

Exercise 2: Tile levels

1. Pick a place in the Northern Hemisphere
2. Find its coordinates
3. Call the tile containing your location for levels 5, 10, & 15

Use this to help!

Exercise 2: Tile levels

1. Go here
2. Replace the lat/long in the url parameters with your own
3. Find a OSM tile url from Exercise 1
4. Replace the Z, X, and Y values with those in your table for levels 5, 10, and 15

X	Y	Z
0	0	0
0	0	1
1	1	2
3	3	3
7	6	4
15	12	5
31	24	6
62	48	7
125	96	8
250	193	9
501	386	10
1002	772	11
2005	1544	12
4011	3089	13
8022	6178	14
16045	12357	15
32090	24715	16
64181	49430	17
128363	98860	18
256726	197721	19

Exercise 2: Tile levels

My Location: Madrid, Spain

Coordinates: 40.4, -3.72

Tile at level 5:

Tile at level 10:

Tile at level 15:

5: **10:** **15:**

Exercise 2: Tile levels

My Location: Madrid, Spain

Coordinates: 40.4, -3.72

Tile at level 5: http://a.tile.openstreetmap.org/5/15/12.png

Tile at level 10: http://a.tile.openstreetmap.org/10/501/386.png

Tile at level 15: http://a.tile.openstreetmap.org/15/16045/12357.png

5: 

10: 

15: 

Back to Our Notebook

Questions?

Contact me:

Email: christyheaton@gmail.com
Twitter: @christytoes
Website: christyheaton.github.io

Survey link:
https://www.surveymonkney.com/r/HNLQ6D2