Introduction to QGIS

Presented by Alexander Abuabara

Nov 17 2025

Presentation and datasets at

https://github.com/abuabara/txgisday2025

DISCLAIMER

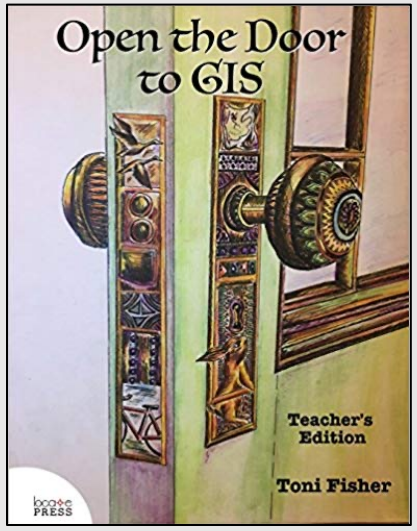
This is rather my personal journey,

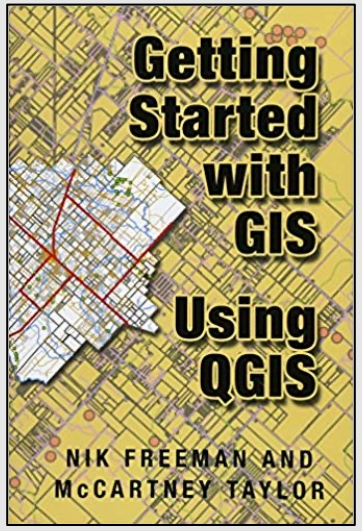
my goal is to give new users a *working knowledge* of QGIS.

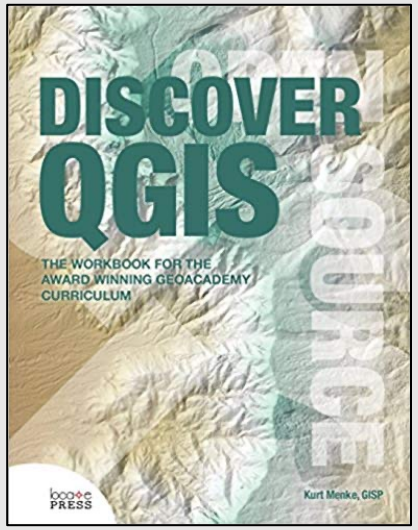
So, this probably doesn't properly answer
"*what is QGIS*" or "*why do I need QGIS*" or "*how can I use QGIS*"

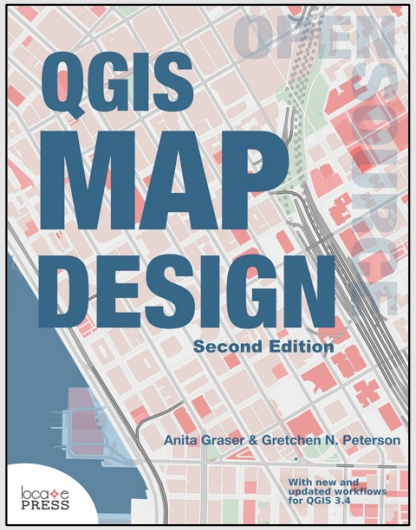
Recommendations:

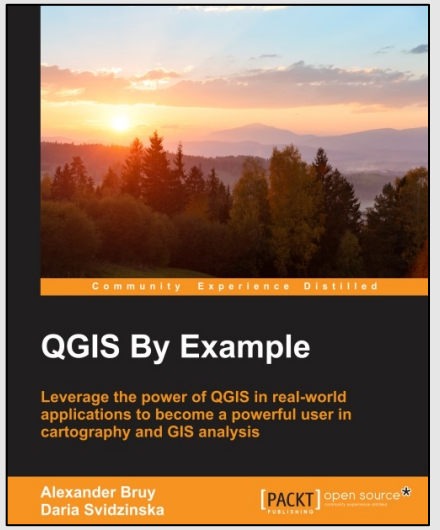
- **GIS Stack Exchange** https://gis.stackexchange.com/
- **QGIS tutorials** https://www.qgistutorials.com/
- and:









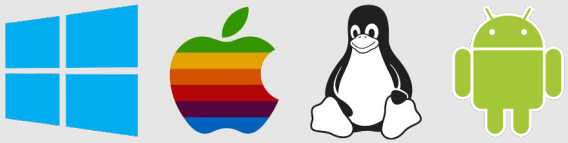


Topics covered during the workshop

- Historical background
- Interface set-up
- You will learn how to obtain, create, manipulate, edit geospatial data by series of tools and commands
- An exercise will be done step by step, along with actual demonstration
- The exercise will make you “connect” the theoretical part of GIS to its actual application
- I am be using QGIS3

A short background …

- Project began in 2002
  - Before v.2 release it was known as Quantum GIS
- Small footprint **(easy to install, even on computers with *few* resources)**
- 64-bit **(no limit of memory use)**
- Multi-operating systems: Windows, MacOS, Linux, & Android



- **Open Source**
  GNU General Public License "guarantees end users (individuals, organizations, companies) the freedoms to use, study, share (copy), and modify the software **(no license harassment!)**

What does QGIS do?

- **View data:**
  - vector (gpkg, shp, MapInfo, SDTS, OGR, etc.)
  - raster (GeoTiff, IMG, ArcInfo Grid, JPEG, PNG, etc.)
  - GRASS data
  - online data served as web services (WMS, WMTS, WCS, WFS, etc.)
- **Explore data:**
  - browse [on-the-fly reprojections]
  - identify and selection tools
  - annotation and labeling
  - edit/view/search attributes
  - save and restore projects
- **Create, edit, manage, and export data:**
  - digitizing vector data
  - create and edit vector, raster, and GRASS data
  - georeferenced images and GPS data tools
  - visualize and download Open Street Map data
  - export to PostGIS, Spatialite Databases, and Atlas (digital and hard-copies)
- **Repeatability/reproducibility:**
  - batch processing made easy: **model builder** and **batch process tool everywhere!**

Because this workshop is a step-by-step process …

You need to do GIS!

- G – Give attention to details
- I – It's as easy as 1, 2, 3
- S – Stay focused but relaxed

QGIS

Openlayers

qvSIG

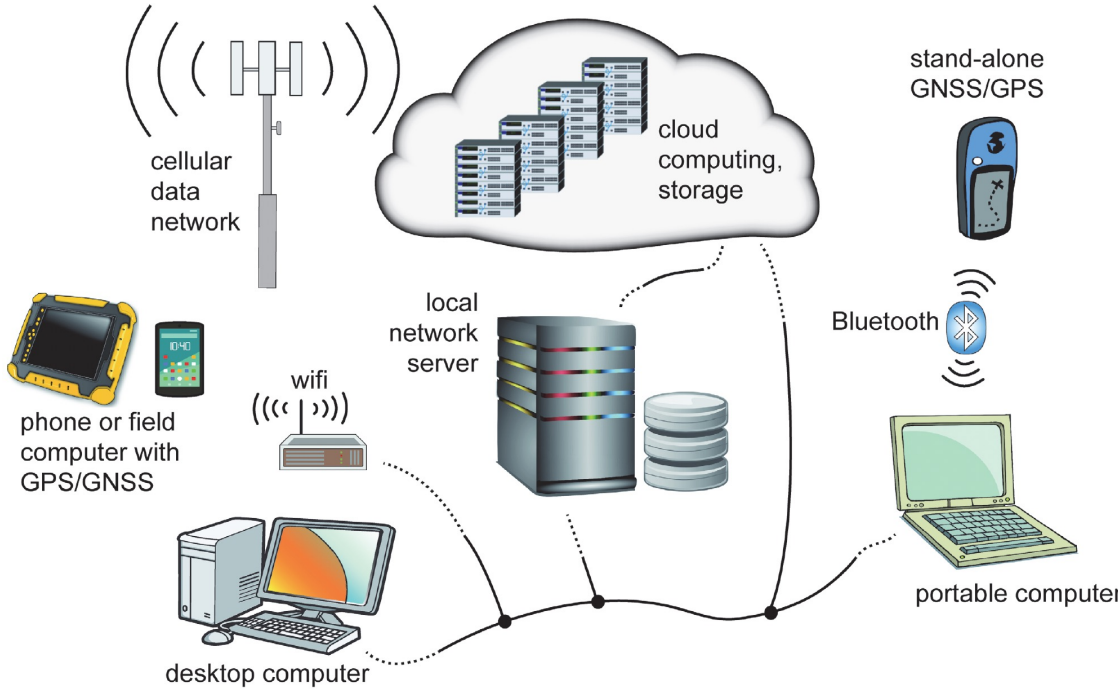
Leaflet

PostGIS-PostgreSQL

GeoServer

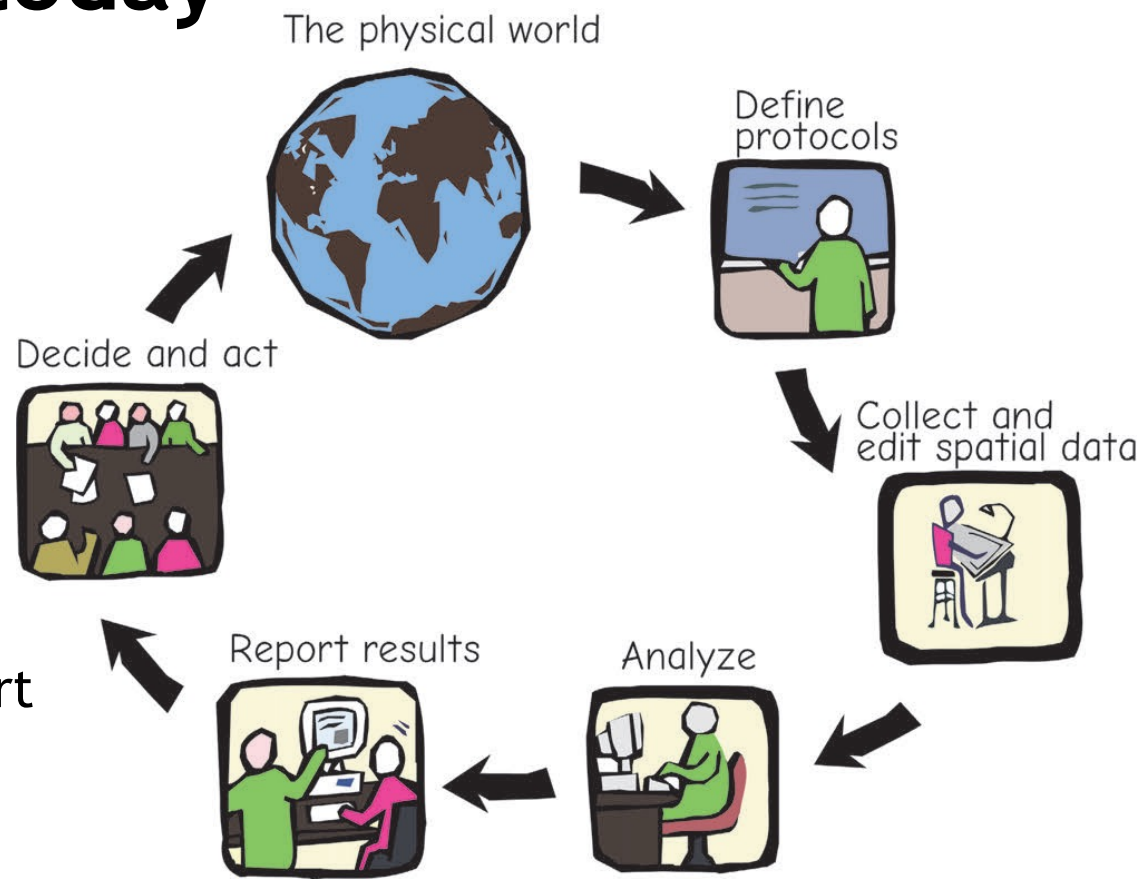
MySQL-spatial

GeoWebCache



Goals for today

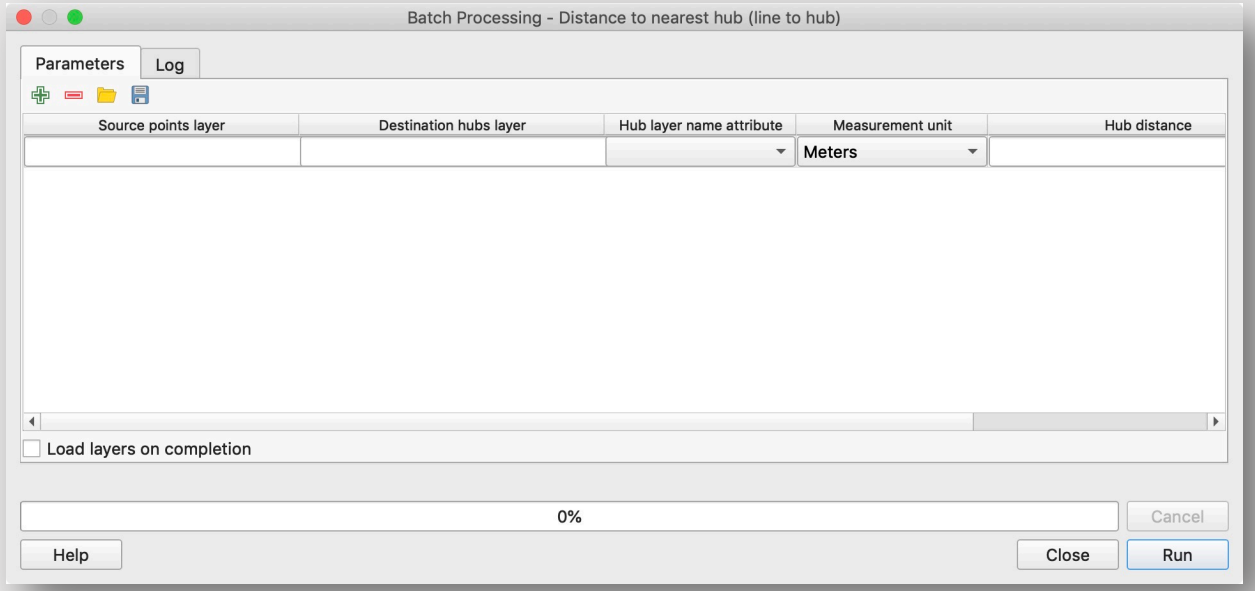
- Import data
- Symbolize it properly (a bit of cartography skills)
- Create bookmarks
- Practice different selection tools
  Check parcel exposure to flood as a proxy to households in risk
- Compose a map that can be used in an atlas or report

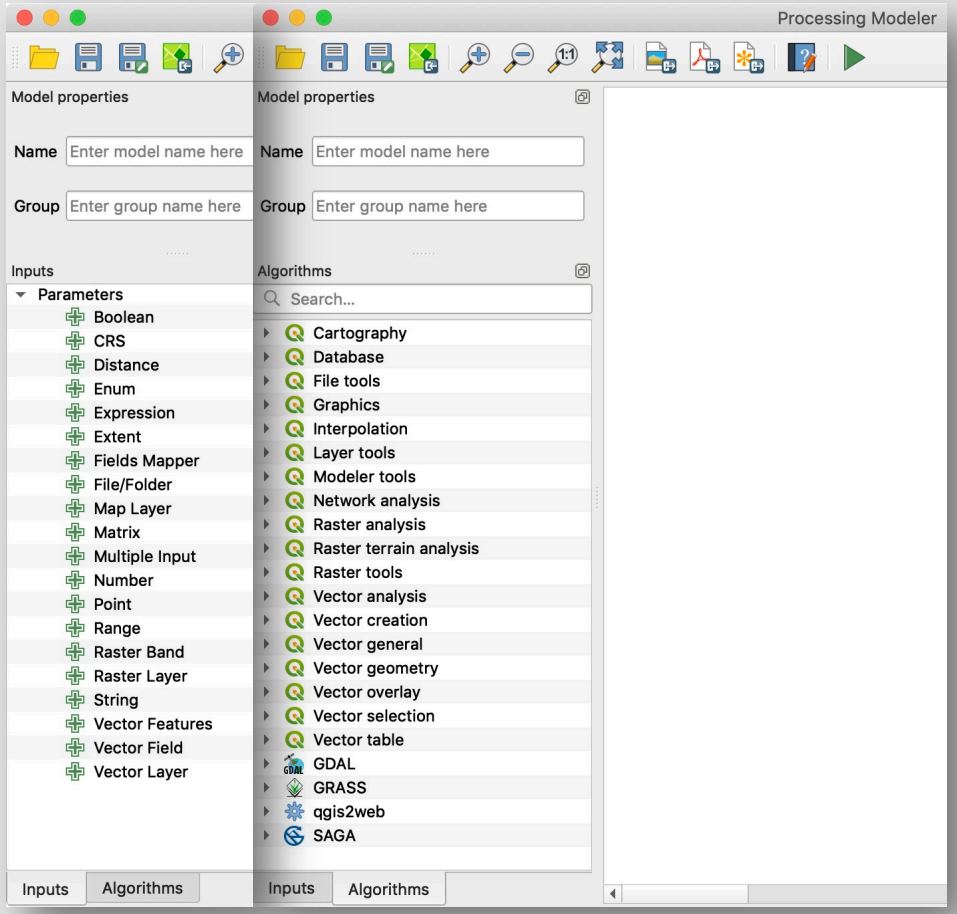


What's after today

- Although we only have time for a handful of operations,
  - I hope that you now have sufficient familiarity with QGIS to explore it further on your own.
- QGIS is constantly being developed,
  - I suggest users periodically check for updates to the software, as new tools are often implemented, and processing and data management protocols are often improved.
  - Explore the **plug-ins** library!
- If you continue expanding your use of QGIS, you may wish to **script** your work for better reproducibility and documentation.
  - **Python** is a common language used for scripting in QGIS.
    find more details on the web
    e.g., http://docs.qgis.org/testing/en/docs/pyqgis_developer_cookbook/intro.html

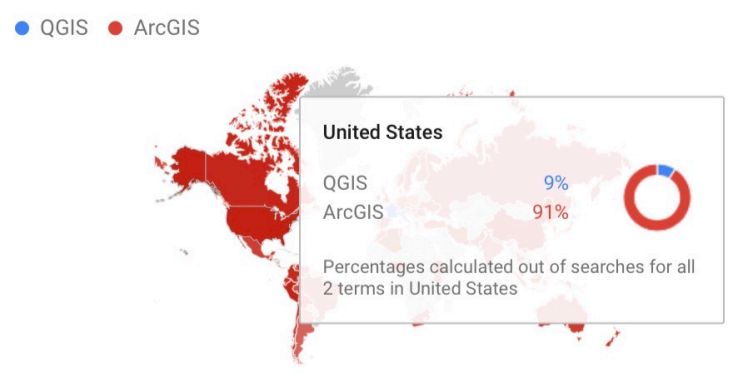
Explore
Batch processing and Graphical modeler

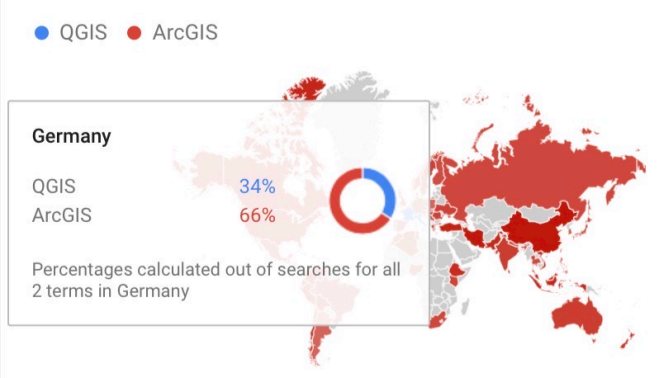


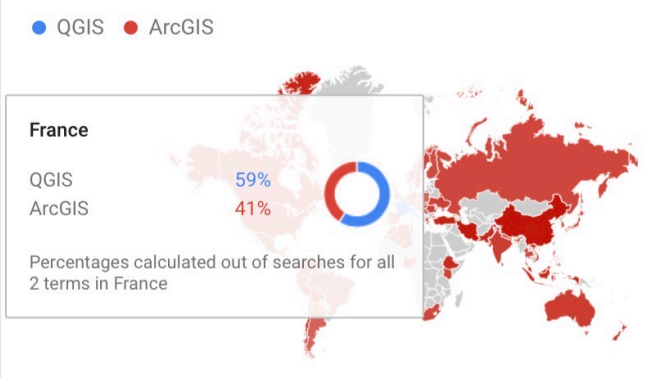


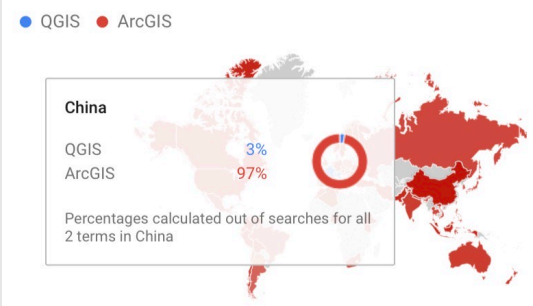
Recommended QGIS plugins

1. **autoSaver**: auto save current project and modified layers in edit mode at specified interval.
2. **Bivariate color polygon renderer**: bivariate color renderer for polygon data.
3. **Digitizing Tools**: meant to be a compilation of tools missing in basic QGIS.
4. **GeoCoding**: allows the user to search for an address and get its coordinates.
5. **Georeferencer Extension**: raster georeferencer.
6. **HCMGIS**: basemaps, download open data, batch converter, projections, and other utilities.
7. **Lat Lon Tools**: tools to capture and zoom to coordinates.
8. **mmqgis**: collection of vector layer operations.
9. **QGIS Cloud**: publish maps on qgiscloud.com
10. **qgis2web**: export to an open layers / leaflet webmap.
11. **QuickMapServices**: easy to use list of services for datasets and basemaps.
12. **QuickOSM**: download OSM data.
13. **Street View**: allows you to open a web page with the Google Street View.

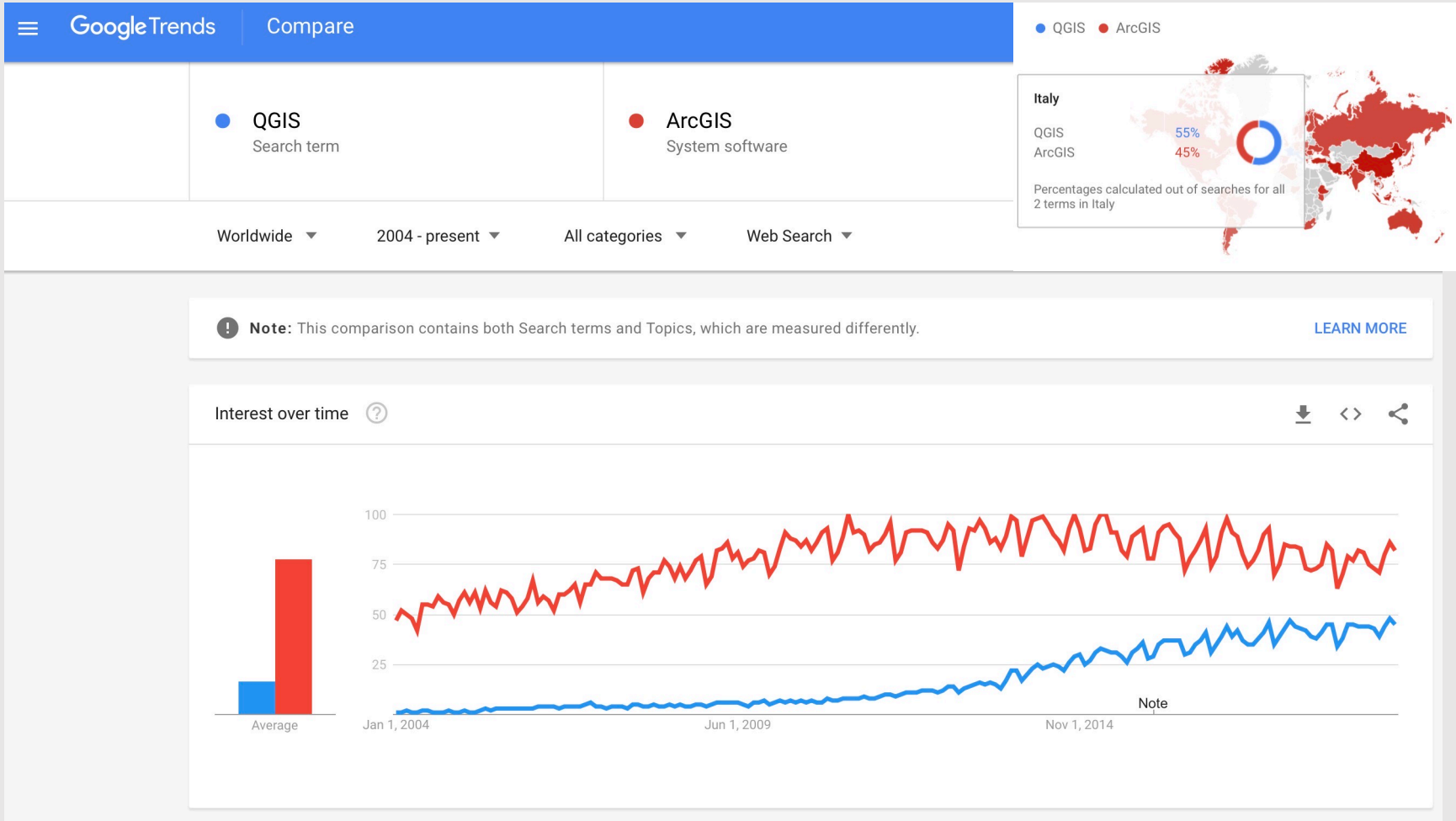

QGIS
ArcGIS
United States
QGIS 9%
ArcGIS 91%
Percentages calculated out of searches for all 2 terms in United States


QGIS
ArcGIS
Germany
QGIS 34%
ArcGIS 66%
Percentages calculated out of searches for all 2 terms in Germany

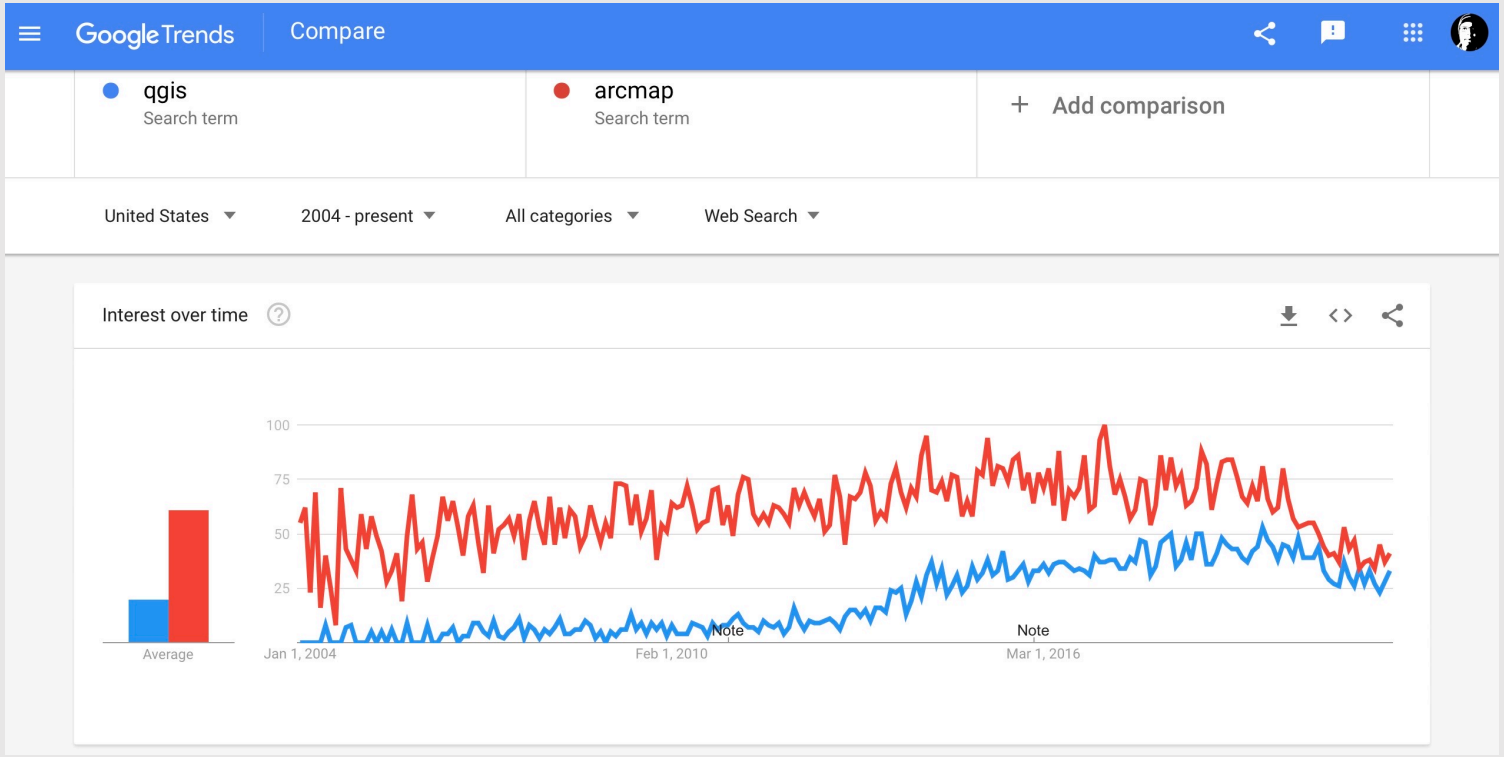

QGIS
ArcGIS
France
QGIS 59%
ArcGIS 41%
Percentages calculated out of searches for all 2 terms in France


QGIS
ArcGIS
China
QGIS 3%
ArcGIS 97%
Percentages calculated out of searches for all 2 terms in China

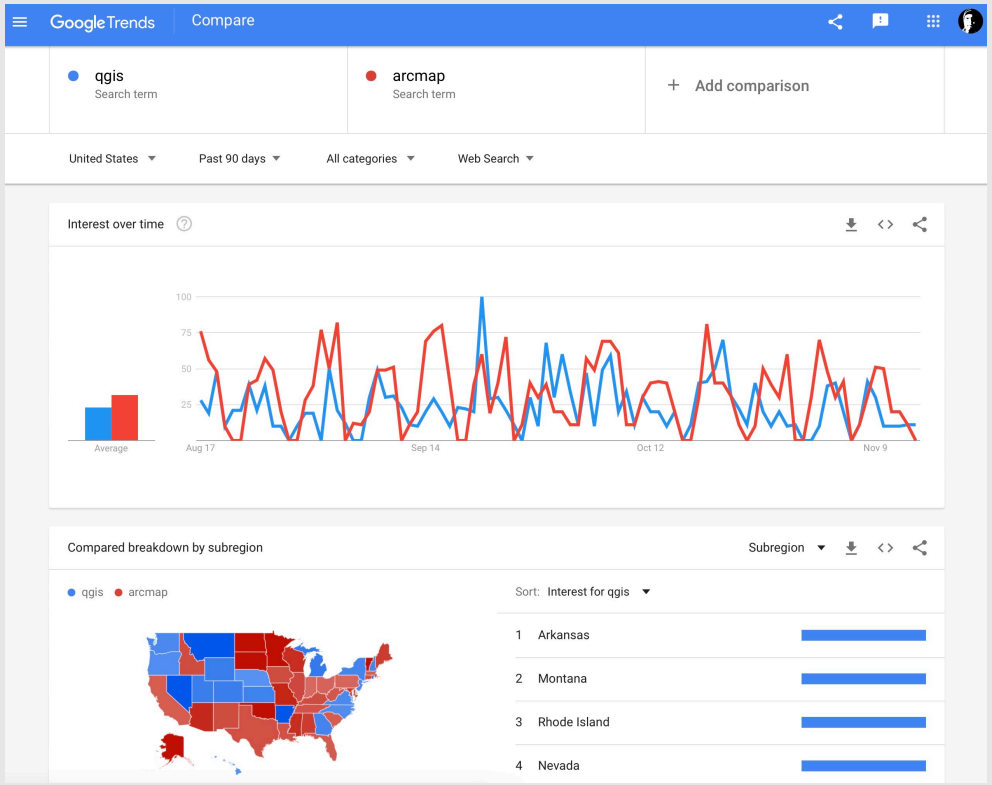
~ 2 years ago!


Google Trends
Compare
QGIS
Search term
ArcGIS
System software
Worldwide
2004 - present
All categories
Web Search
Note: This comparison contains both Search terms and Topics, which are measured differently.
LEARN MORE
Interest over time
100
75
50
25
Note
Average
Jan 1, 2004
Jun 1, 2009
Nov 1, 2014

QGIS
ArcGIS
Italy
QGIS 55%
ArcGIS 45%
Percentages calculated out of searches for all 2 terms in Italy

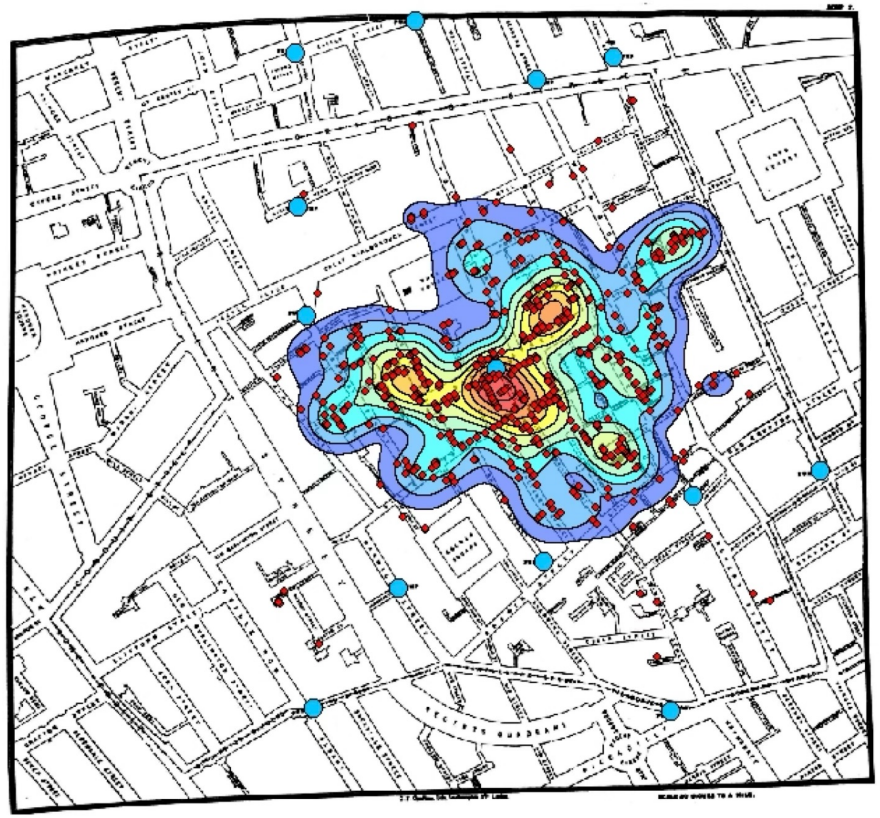

Google Trends
Compare
qgis
Search term
arcmap
Search term
Add comparison
United States
2004 - present
All categories
Web Search
Interest over time
100
75
50
25
Average
Note
Note
Jan 1, 2004
Feb 1, 2010
Mar 1, 2016

as of today!


Google Trends
Compare
qgis
Search term
arcmap
Search term
Add comparison
United States
Past 90 days
All categories
Web Search
Interest over time
100
75
50
25
Average
Aug 17
Sep 14
Oct 12
Nov 9
Compared breakdown by subregion
Subregion
qgis
arcmap
Sort: Interest for qgis
1 Arkansas
2 Montana
3 Rhode Island
4 Nevada

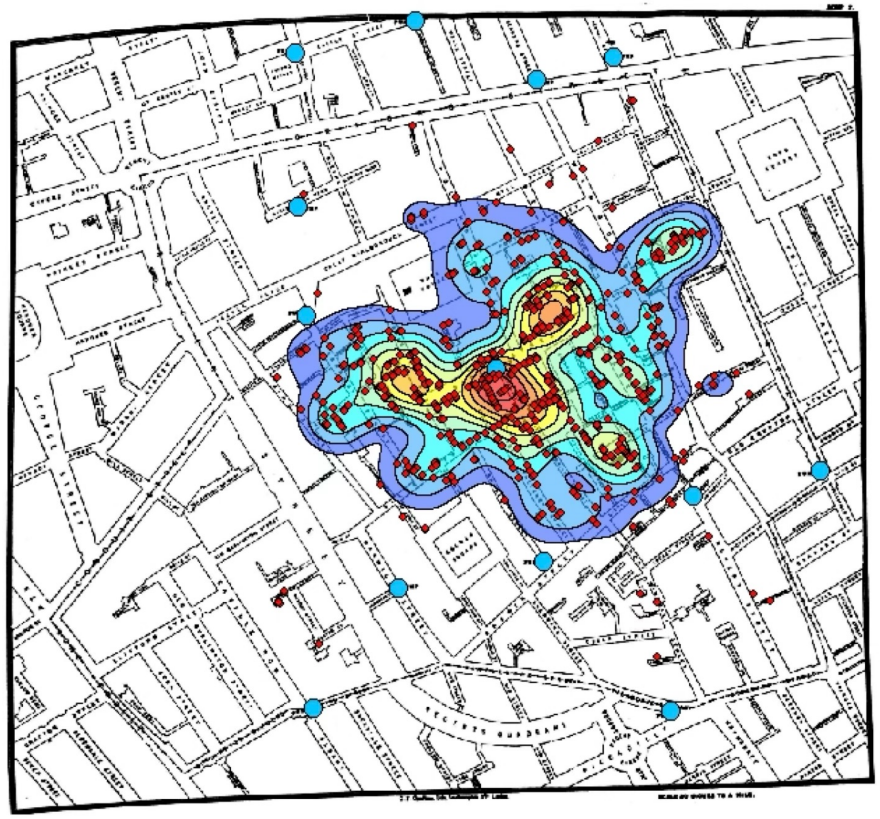
Uses of Spatial Data in Science

- Spatial analysis using location or spatial relationships as an explanatory or predictive variable
- Examining the effects of scale
- Backdrops to show context



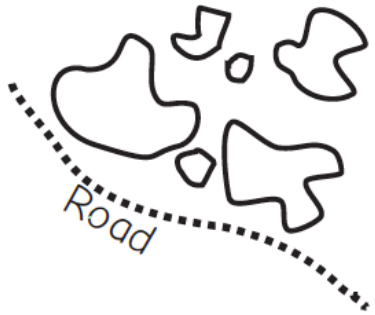
Challenges with Spatial Data

- **Incomplete or inaccurate locations**
  Missing coordinates, wrong geocoding, or imprecise measurements.
- **Inconsistent formats**
  Data collected with different projections, scales, or precision levels.
  - **Noise and errors**
  - **Different coordinate reference systems** (CRS)
    Converting between systems can introduce more distortions or errors
- **Large Data Volumes**: slow to visualize, query, or analyze in standard tools.
- **Spatial Complexity**: require specialized algorithms and data structures.
- **Data Integration & Interoperability:** requires consistency
- **Temporal Dynamics (Space-Time)**: spatial phenomena change over time.
- **Privacy & Confidentiality**: data can be highly sensitive, ethical use.
- **Uncertainty & Ambiguity**: not clarity on boundaries of features.
- **Visualization Challenges**: nontrivial, requires good cartographic design.
- **Specialized Tools & Skills**: steeper learning curve than standard data analysis.

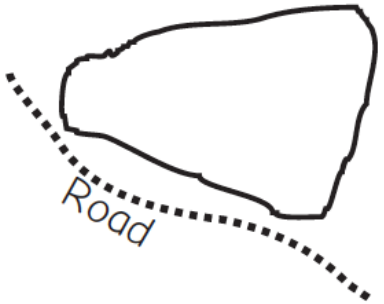


Cartographic generalizations

Truth

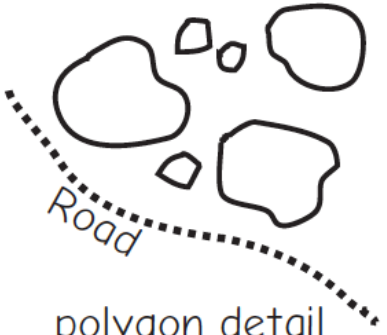


Fused



polygons fused

Simplified

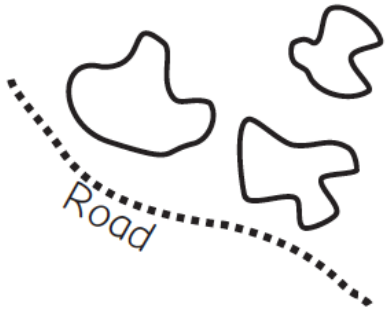


polygon detail simplified

Displaced

road displaced from polygons

Omitted

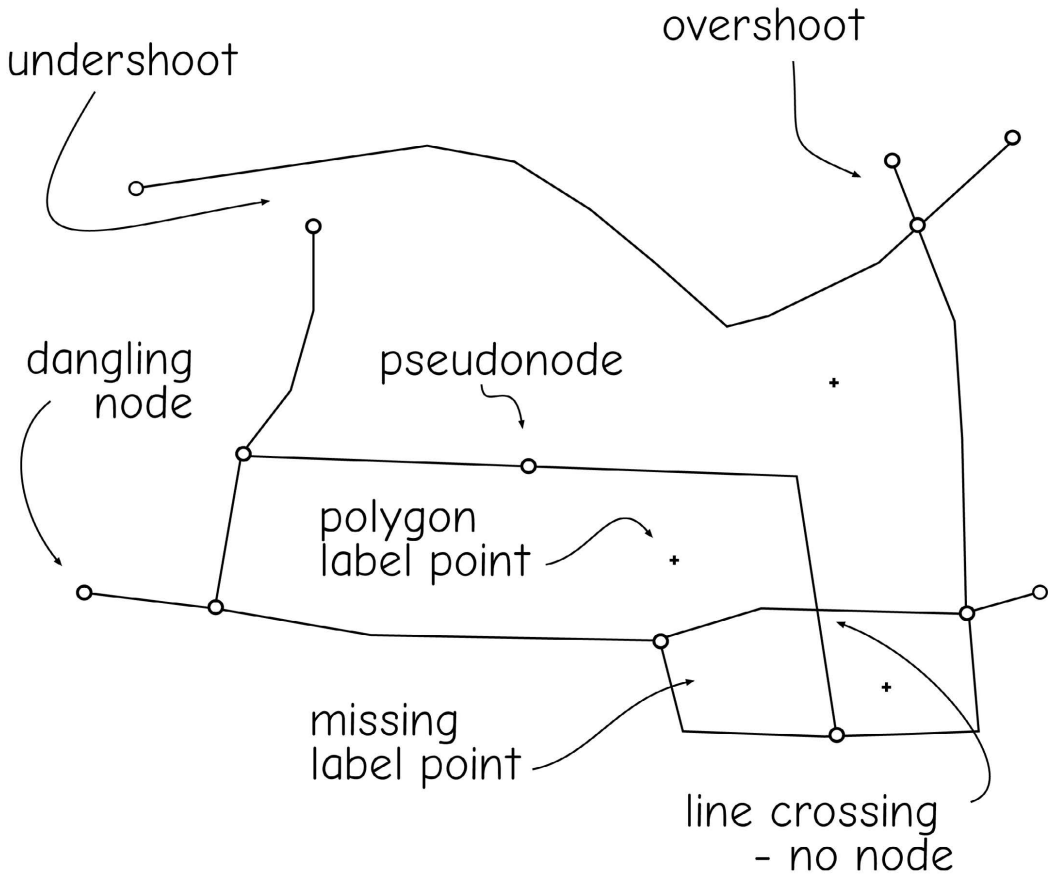


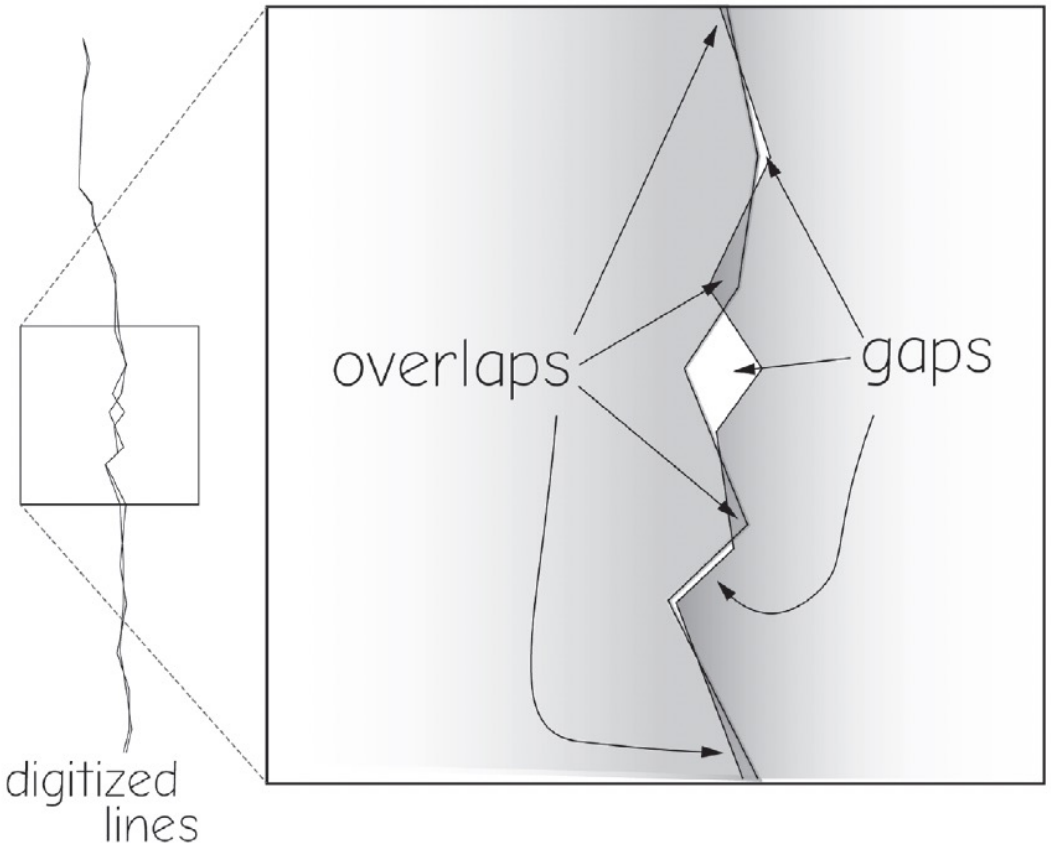
small polygons omitted

Exaggerated

exaggerated road width due to standard symbol

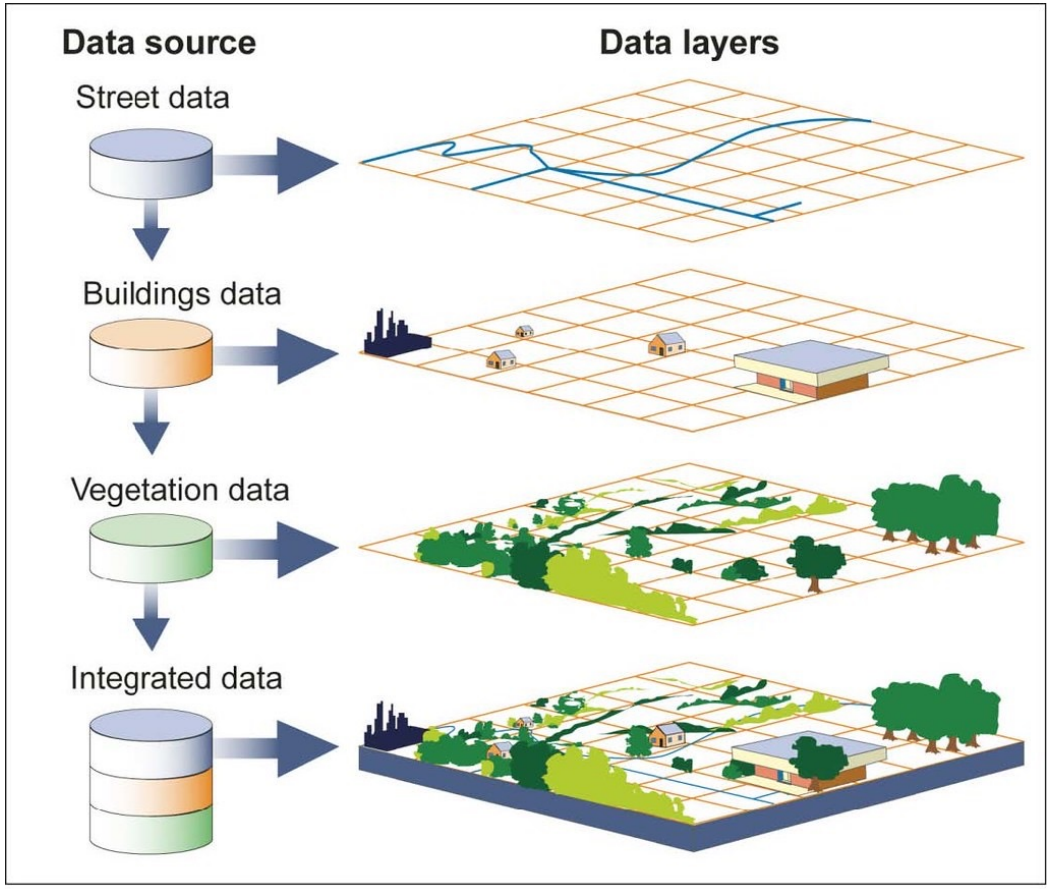
Common digitizing errors





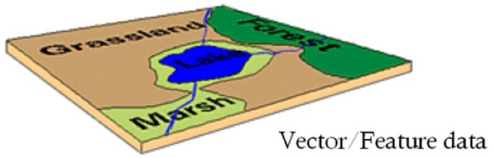
Getting Started

Representing Physical Features

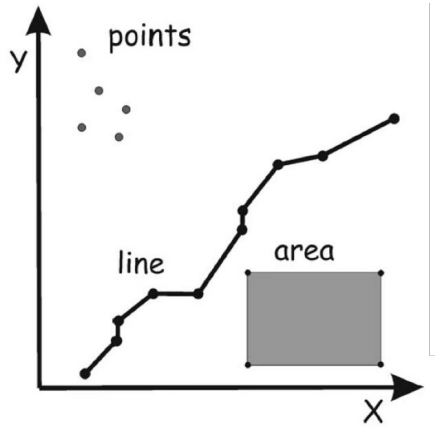


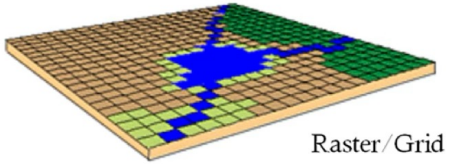
Data models for representing digitally geographic data:

- Raster
- Vector

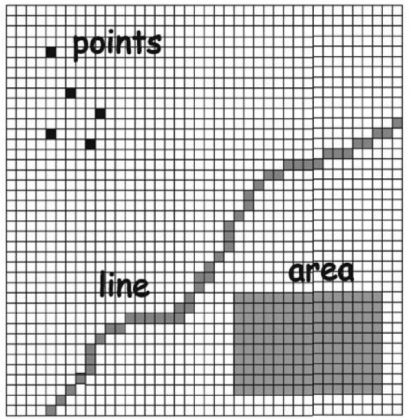


Vector/Feature data





Raster/Grid data



Creating Spatial Objects

- Three options:
  - from scratch (e.g., digitizing, geocoding)
  - "promote" a data frame including a geometry column (e.g., Census)
  - import a GIS file (e.g., shapefiles, raster, geopackages)

Real World

Phenomena exist

Data Model

Abstraction of phenomena and properties

Shape	Area	Stl_wetlk	Attribute
Polygon	280290.98165	580	PEM/SS1Bdg
Polygon	1630.52135	581	PUBGx
Polygon	16229.73690	582	U
Polygon	792.66535	583	PEMC
Polygon	1218.39765	584	PSS1C
Polygon	1294.57970	585	U
Polygon	1009.27755	586	PUBGx
Polygon	5928.50895	587	PUBGx
Polygon	1028.50440	588	PEMC
Polygon	9969.29615	589	PUBGx
Polygon	6894.33895	590	PUBGx

Data Structure

1.2 ,	4.7
5.8 ,	3.6
8.9 ,	7.2
.	
.	

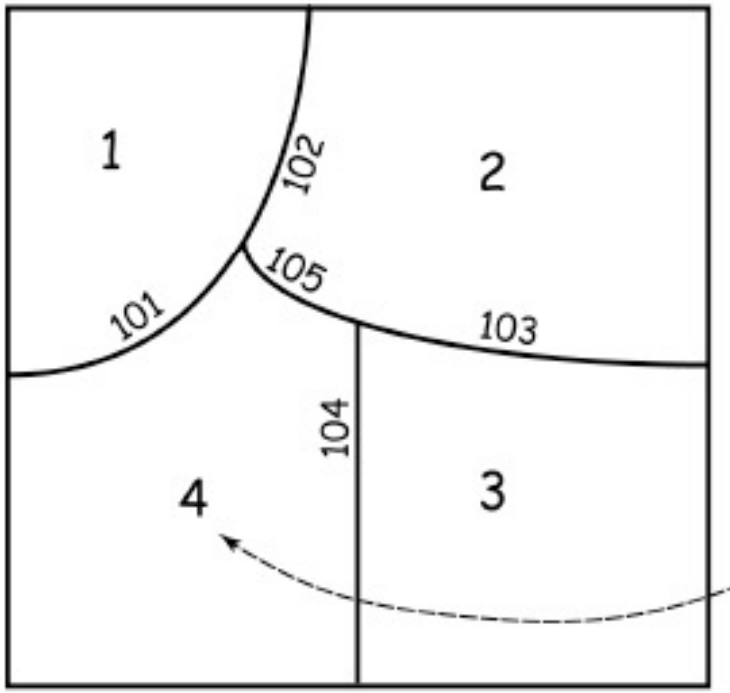
Computer representation

Attribute

Record

GEOID	NAME	total_pop	area	density
45	South Carolina	5118425	80574.2109 [km^2]	63.524358
04	Arizona	7151502	295229.8796 [km^2]	24.223503
10	Delaware	989948	5207.0643 [km^2]	190.116339
11	District of Columbia	689545	176.9277 [km^2]	3897.326743
09	Connecticut	3605944	12923.6096 [km^2]	279.019880
33	New Hampshire	1377529	24036.2885 [km^2]	57.310387
31	Nebraska	1961504	200332.4264 [km^2]	9.791246
53	Washington	7705281	175330.7941 [km^2]	43.947106
48	Texas	29145505	687675.6379 [km^2]	42.382634
39	Ohio	11799448	106856.7719 [km^2]	110.423025
55	Wisconsin	5893718	145335.5729 [km^2]	40.552481
41	Oregon	4237256	251333.3413 [km^2]	16.859108
28	Mississippi	2961279	123470.5796 [km^2]	23.983681

Geographic Depiction



Attribute Table

ID	type	area
1	big	16.8
2	little	22.2
3	mid	18.4
4	tiny	20.7

What you see

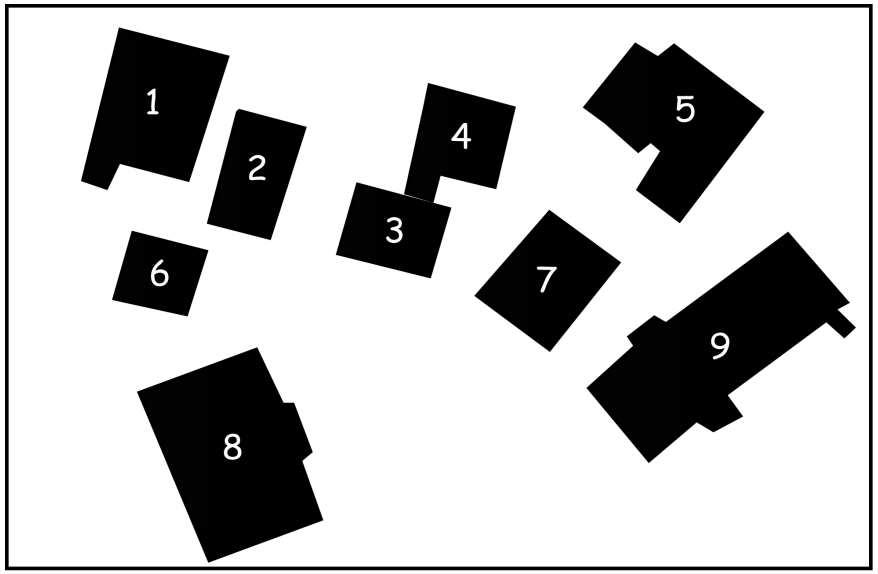
What you don't see

Polygon	Lines
1	101, 102,...
2	102, 103,...
3	103, 104,...
4	104, 101,...

N & V	Type	X	Y
21	v	124.7	155.2
35	n	202.2	150.9
47	v	16.3	35.5
94	n	135.5	22.2
....	....	....	....

Line	Nodes & Vertices
101	58, 47, 48, 49, 50, ...
102	71, 72, 73, 74, 75, ...
103	35, 21, 22, 23, 24, ...
104	94, 79, 80, 81, 82, ...
....	....

Topology & Coordinate Data



ID	Building Name	Floors	Roof Type
1	Hodson Hall	6.0	flat, sealed tar
2	Borlaug Hall	5.5	pitched 9/12, tile
3	Guilford Technology Bldg.	4.0	flat, gasket
4	Shop Annex	2.5	flat, sealed tar
5	Animal Sciences Bldg.	1.0	pitched 12/12, tile
6	Administration Bldg.	14.0	pitched 6/12, metal
7	Climate Sciences Center	6.0	flat, sealed tar
8	Grantham Tower	1.0	pitched, 9/12, tile
9	Biological Sciences Bldg.	9.0	pitched 12/12, tile

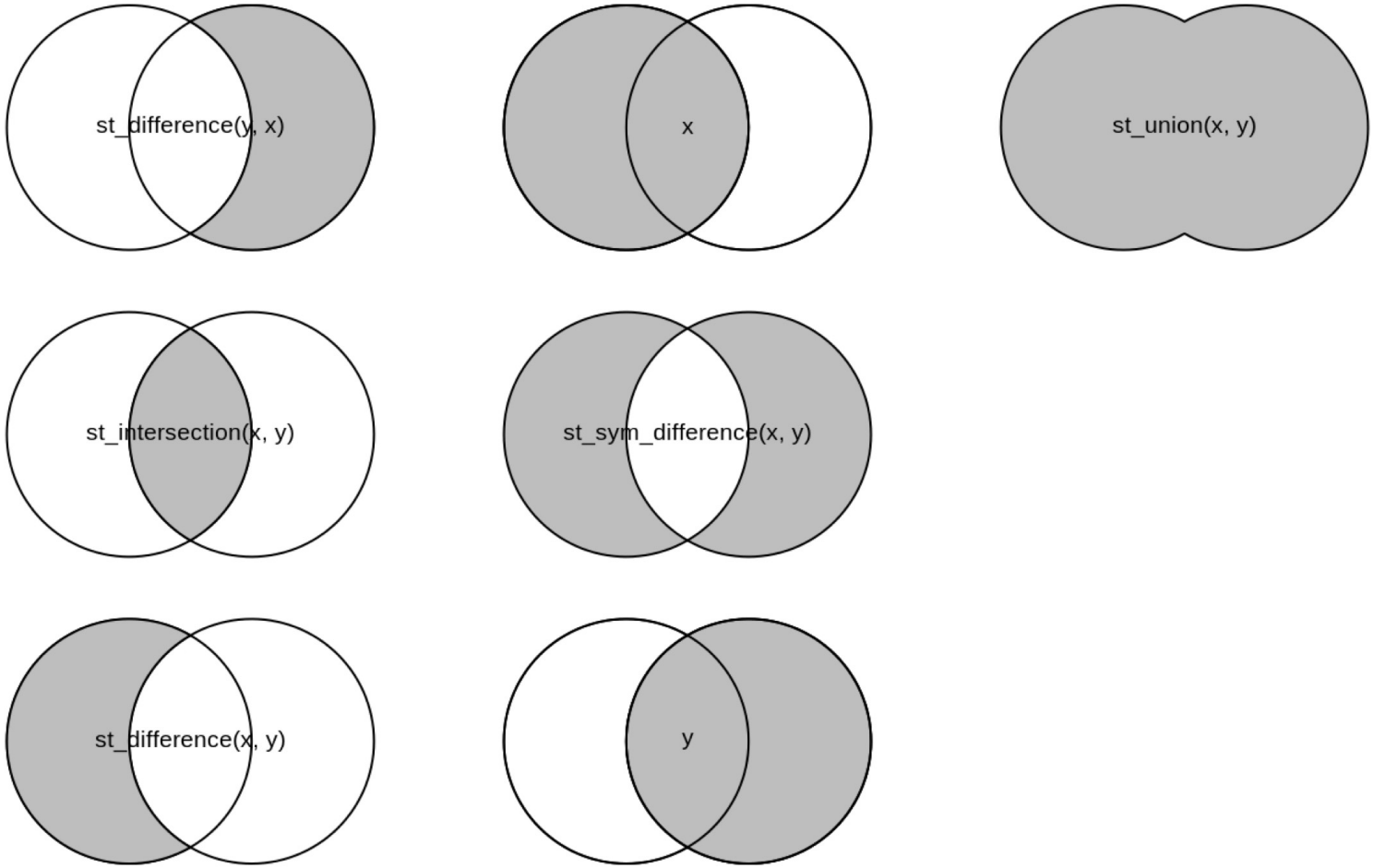
Spatial Vector Data
Geometry Types

- By features it mean things that have a geometry, and eventually other attributes.
- The big seven
(most commonly used geometries):

type	description
`POINT`	single point geometry
`MULTIPOINT`	set of points
`LINESTRING`	single linestring (two or more points connected by straight lines)
`MULTILINESTRING`	set of linestrings
`POLYGON`	exterior ring with zero or more inner rings, denoting holes
`MULTIPOLYGON`	set of polygons
`GEOMETRYCOLLECTION`	set of the geometries above

Spatial Vector Data

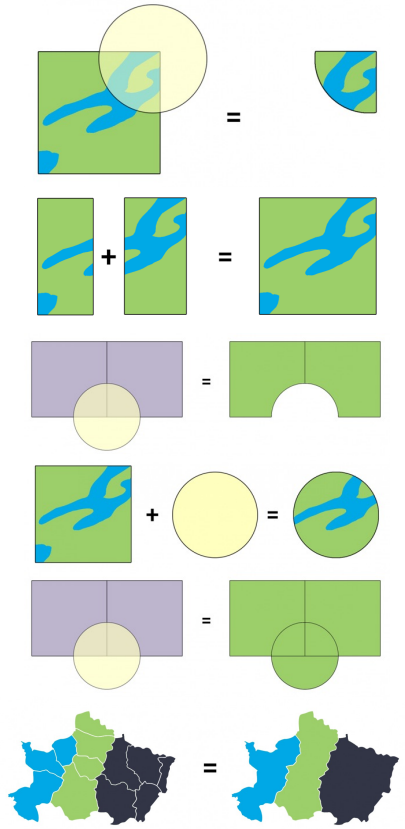
Spatial equivalents of logical operators



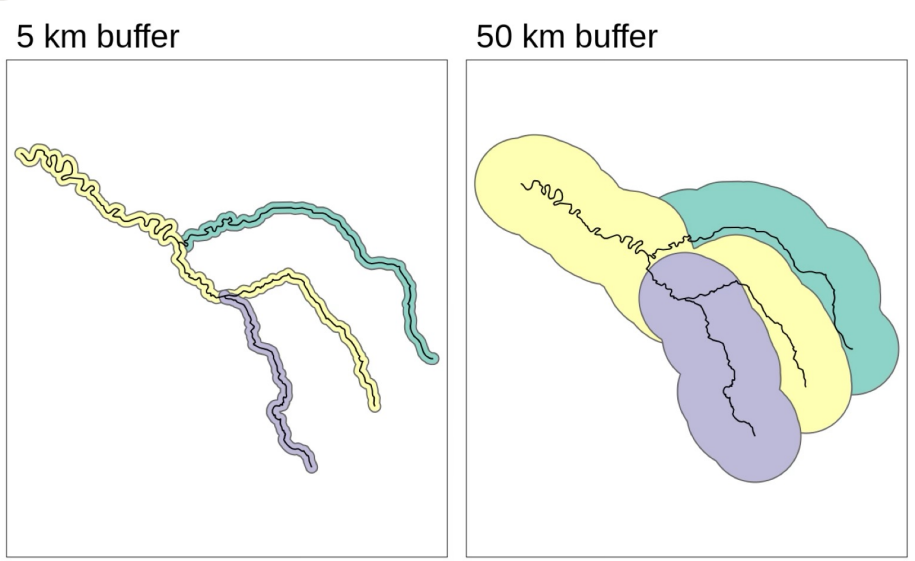
Overlay analysis tools in GIS

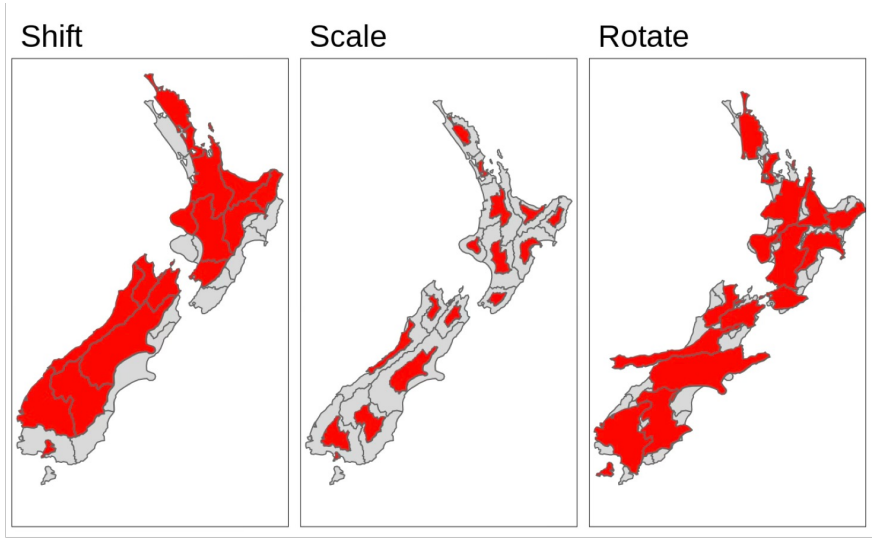
Each overlay operation has its unique application. But the goal is to understand spatial relationships between geographic features.

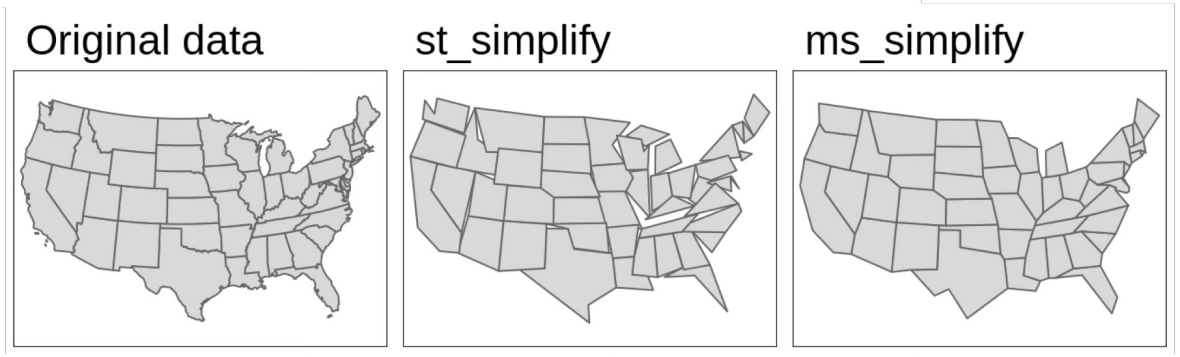
- Intersect
- Merge
- Erase
- Clip
- Union
- **Dissolve**



Spatial Vector Data
Many other spatial operations

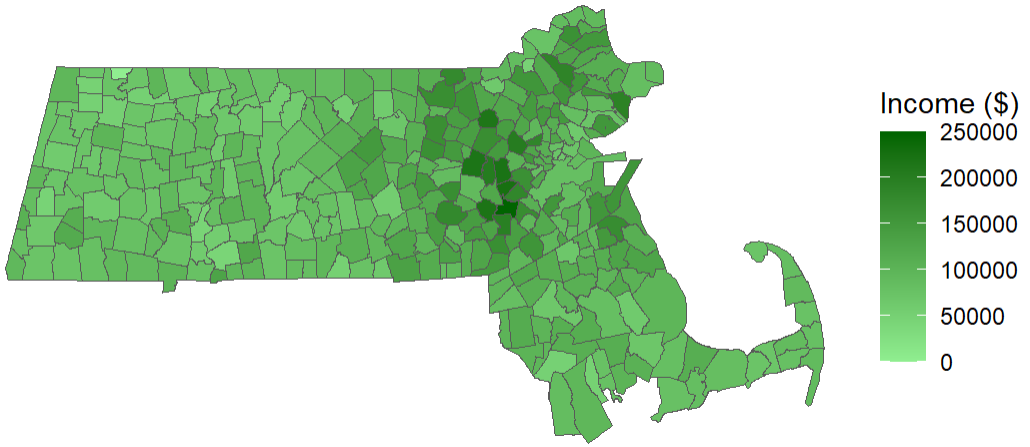






Statistical distribution maps

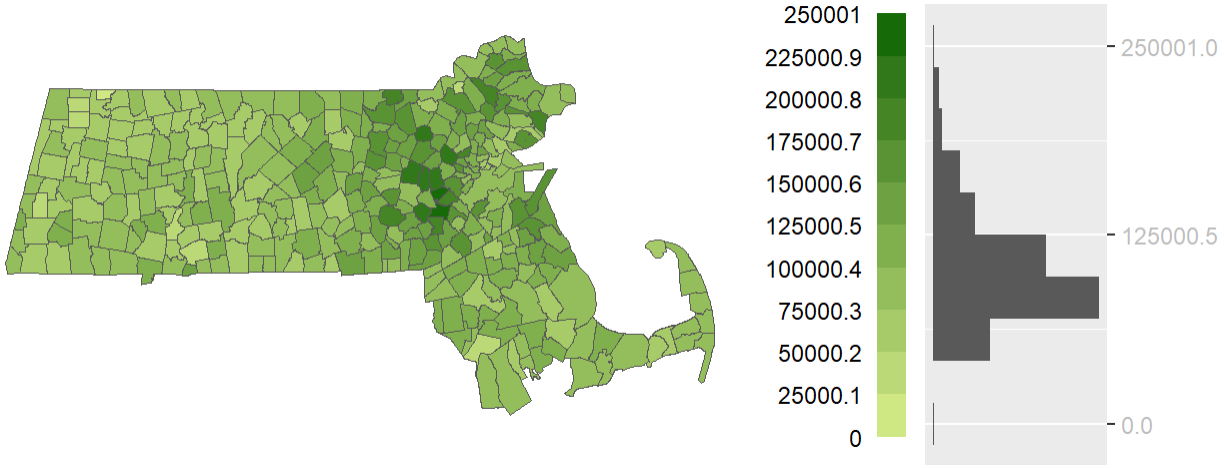
Example of a continuous color scheme applied to a choropleth map.



Such a map (continuous) may not be as informative as one would like it to be. In statistics, we seek to reduce large sets of continuous values to discrete entities to help us better "handle" the data.

Equal interval

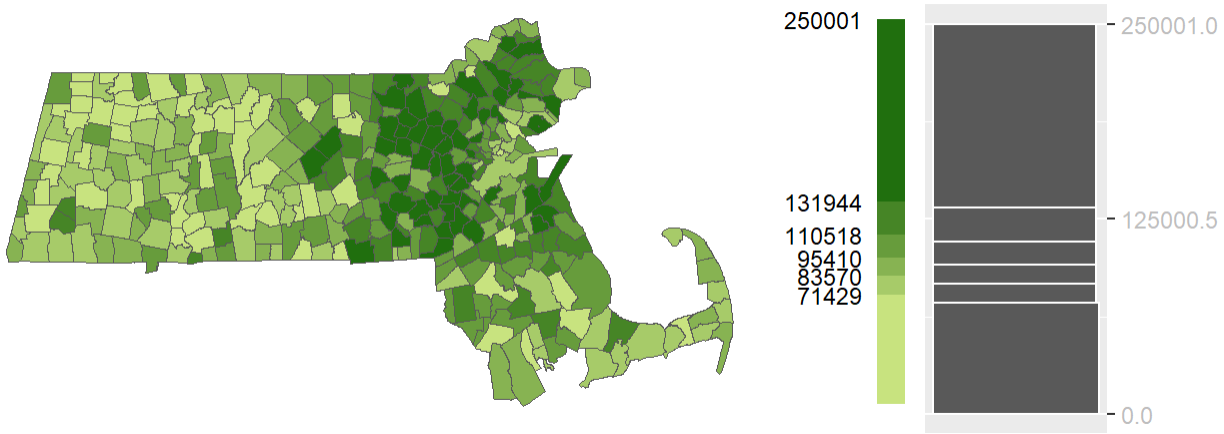
An equal interval choropleth map using 10 bins.



In the field of statistics, discretization of values can take on the form of a histogram where values are assigned to one of several equal width bins. A choropleth map classification equivalent is the equal interval classification scheme.

Quantile map

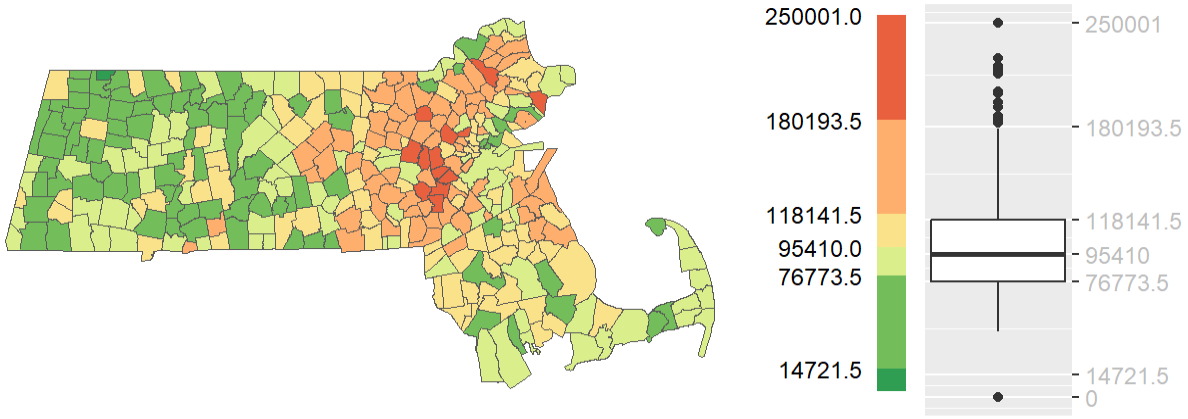
Example of a quantile map.



While an equal interval map benefits from its intuitiveness, it may not be well suited for data that are not uniformly distributed across their range. Quantiles define ranges of values that have equal number of observations. Six quantiles with each quantile representing the same number of observations.

Boxplot map

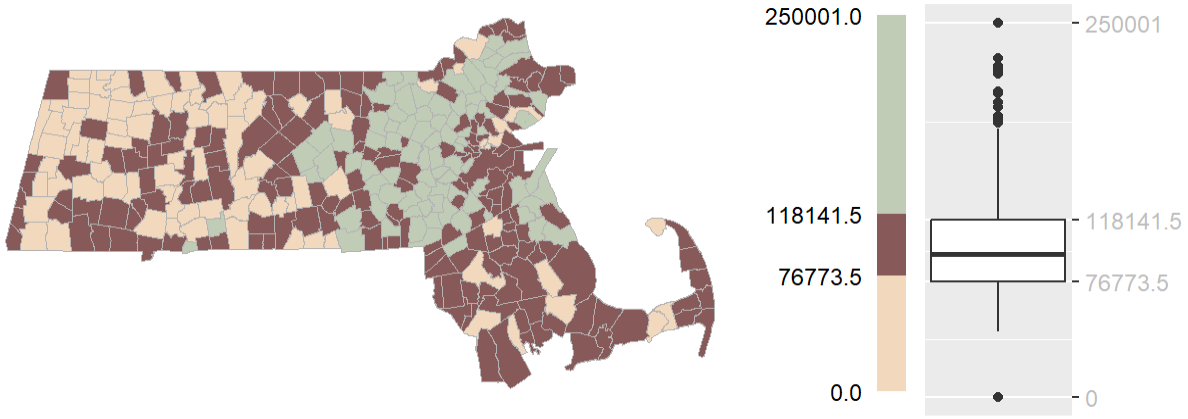
Example of a boxplot map.



The discretization of continuous values can also include measures of centrality (e.g. the mean and the median) and measures of spread (e.g. standard deviation units) with the goal of understanding the nature of the distribution such as its shape (e.g. symmetrical, skewed, normal) and range.

IQR map

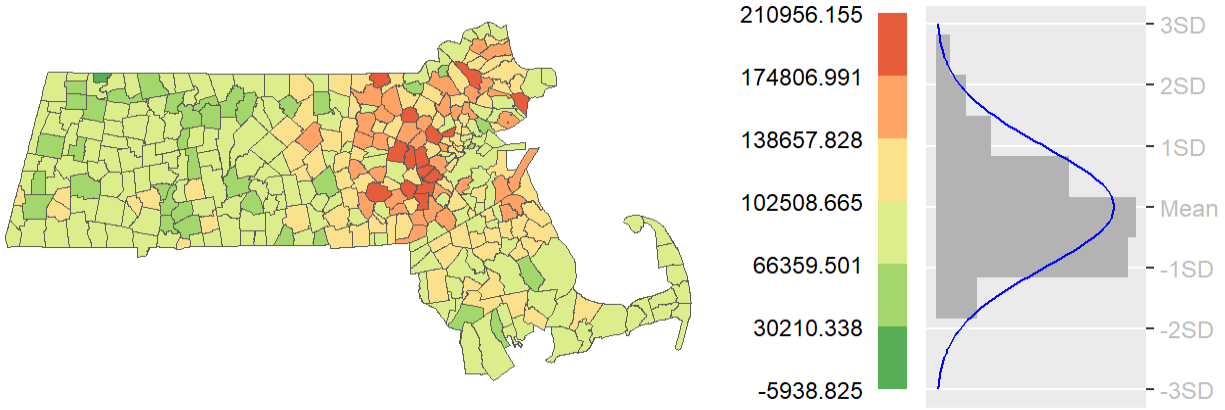
Example of an IQR map.



The IQR map is a reduction of the boxplot map whereby we reduce the classes to just three: the interquartile range (IQR) and the upper and lower extremes.

Standard deviation map

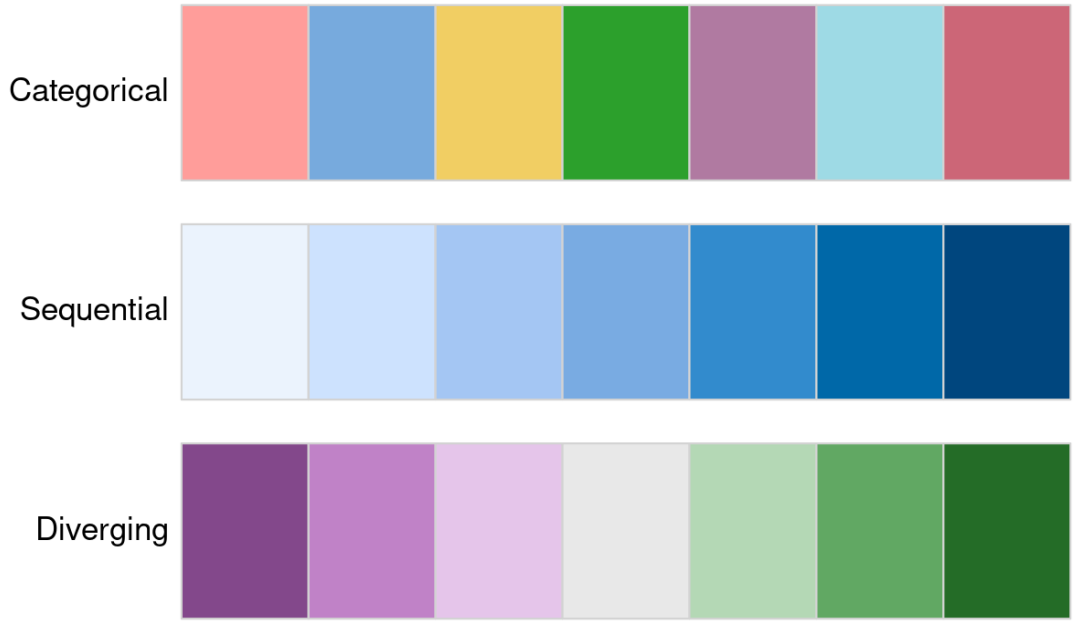
Example of a standard deviation map.

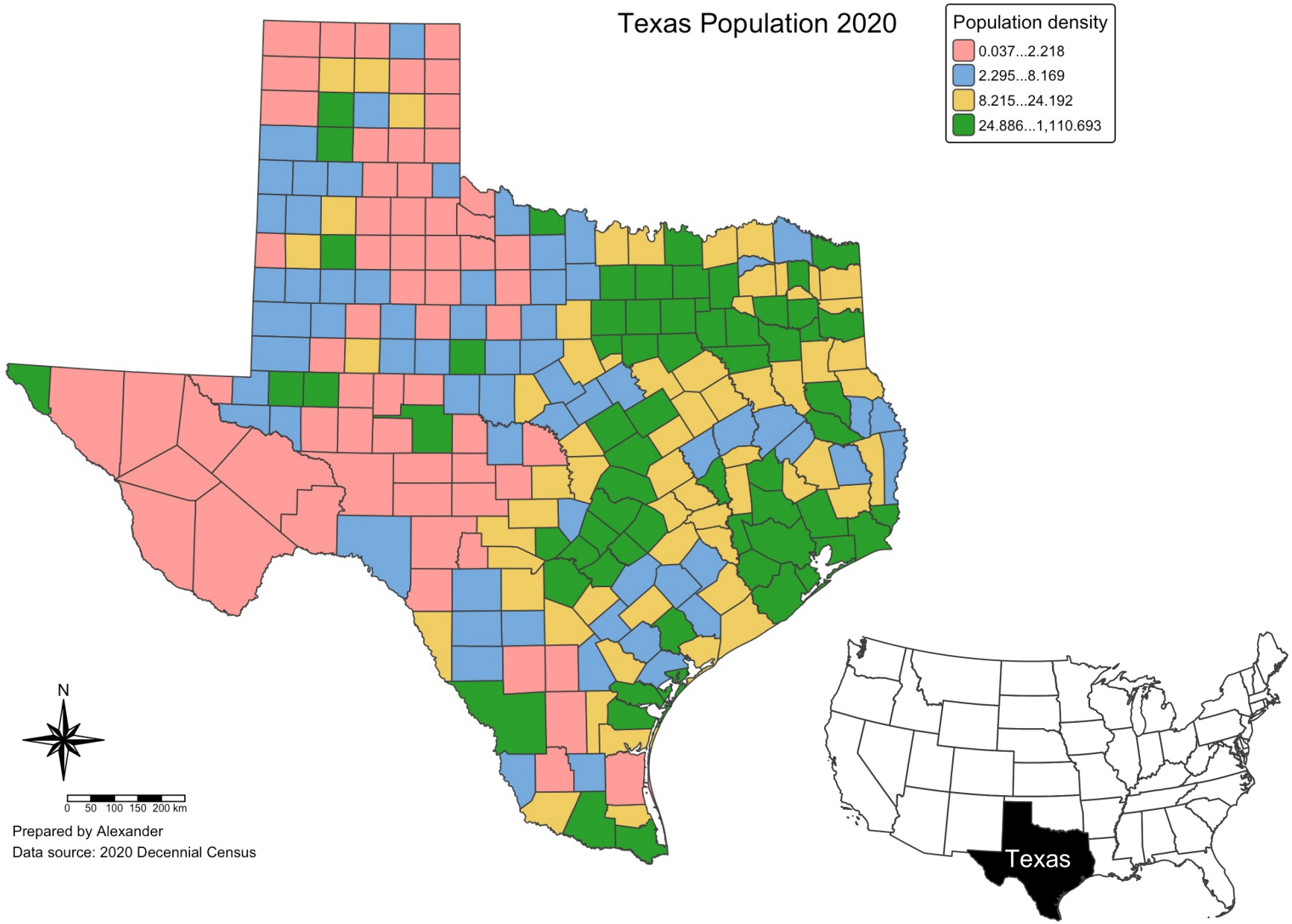


Note from the figure that the income data do not follow a Normal distribution exactly; they have a slight skew toward higher values. This results in more polygons being assigned higher class breaks than lower ones.

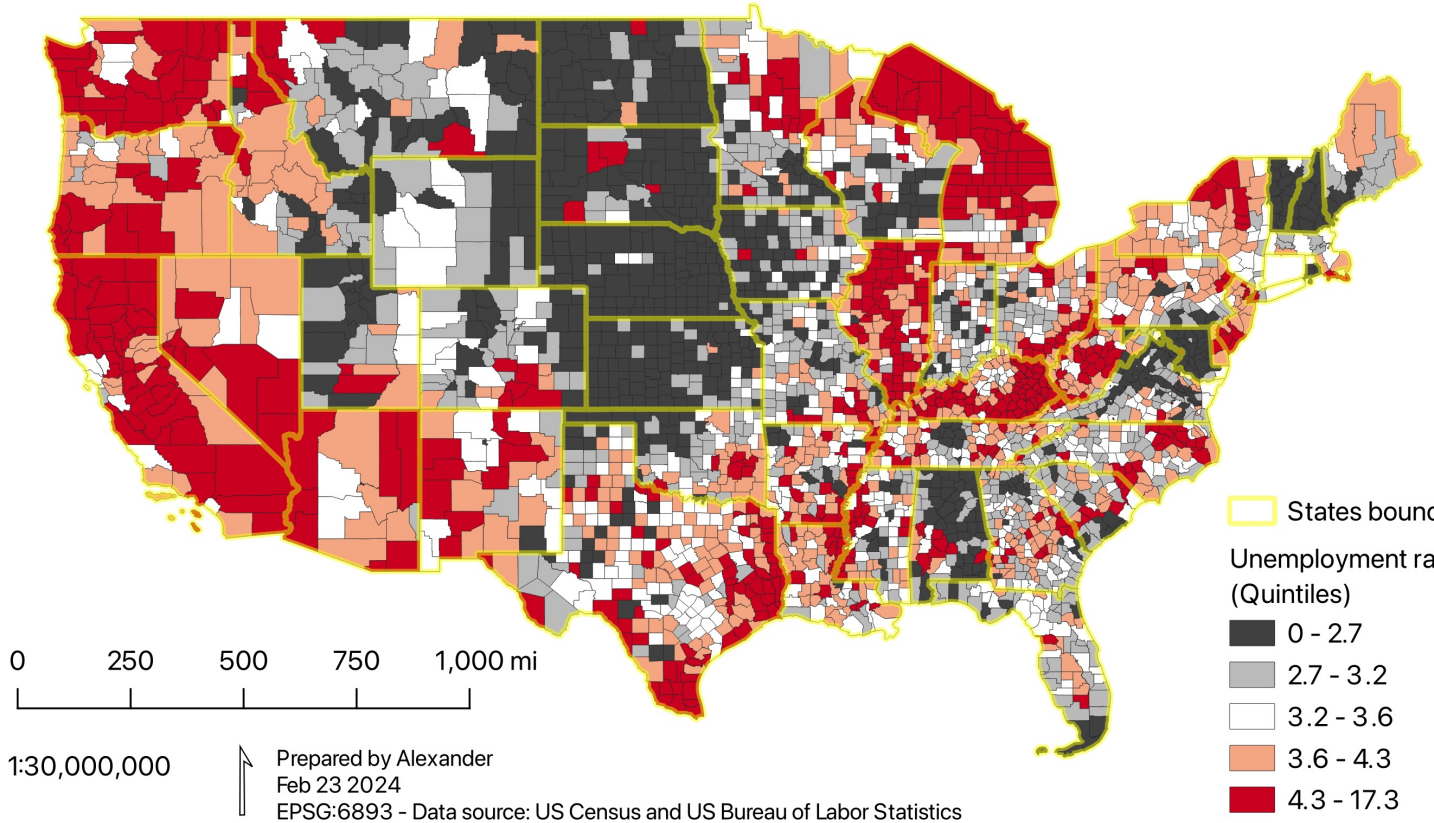
Color ramps

There are three main groups of color palettes:




Texas Population 2020
Population density
0.037...2.218
2.295...8.169
8.215...24.192
24.886...1,110.693
N
0 50 100 150 200 km
Prepared by Alexander
Data source: 2020 Decennial Census
Texas

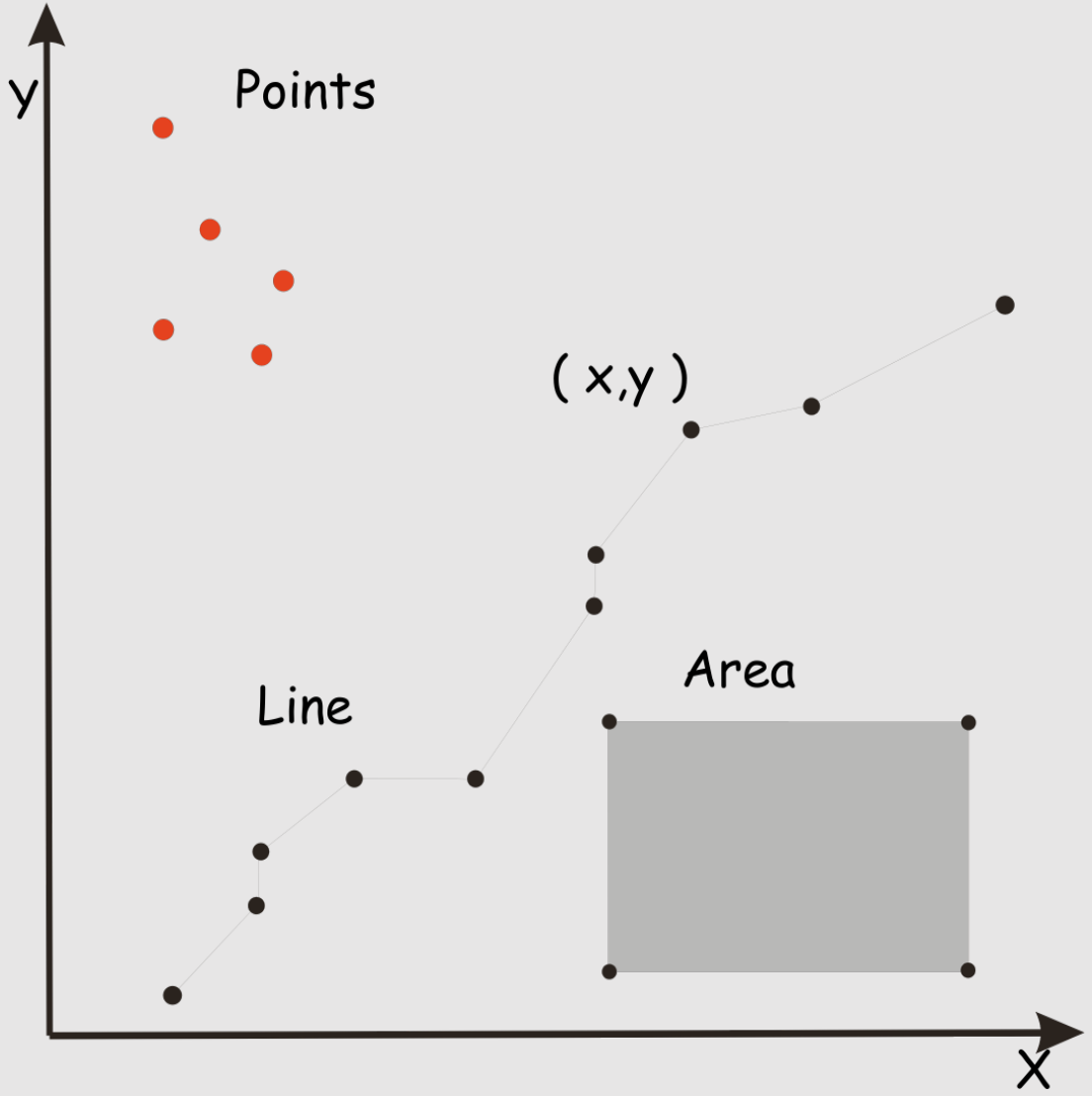
US Labor Force Unemployment by County
2023 Annual Averages



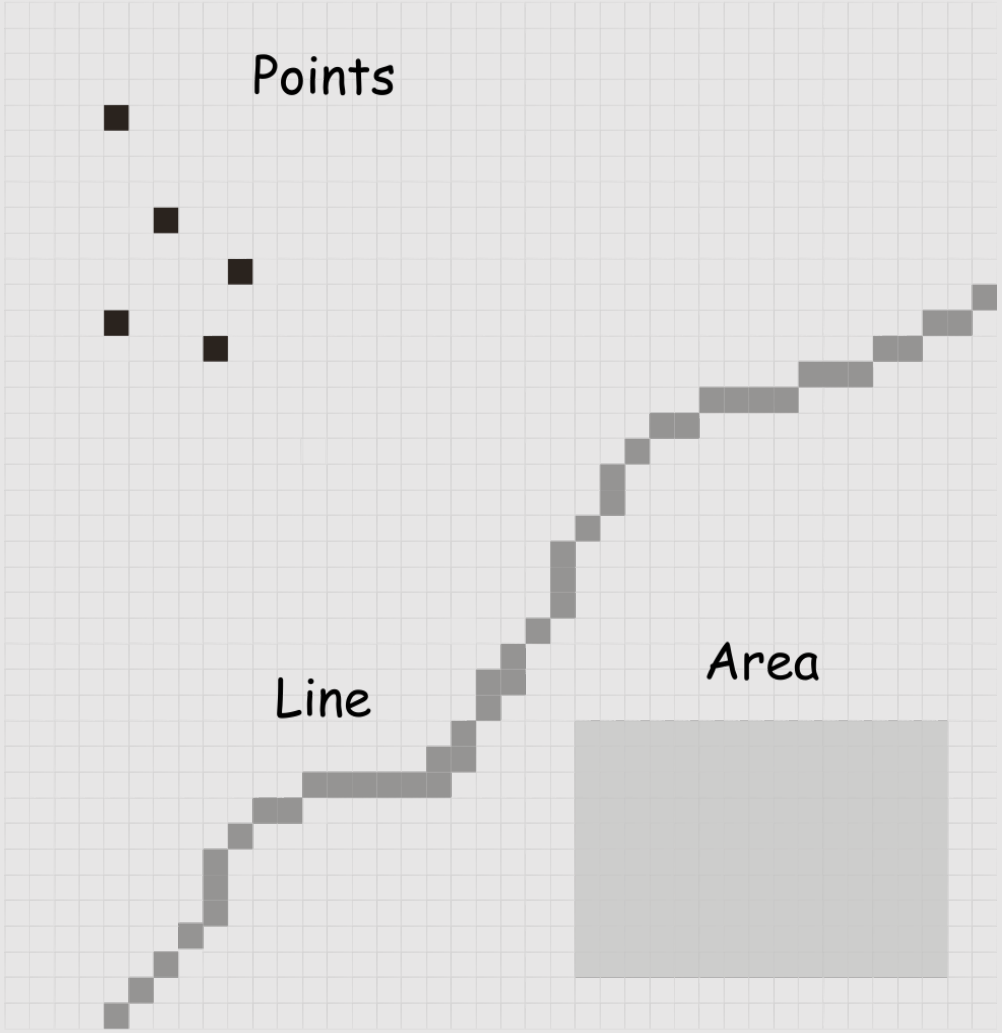
1:30,000,000

Prepared by Alexander
Feb 23 2024
EPSG:6893 - Data source: US Census and US Bureau of Labor Statistics

Vector

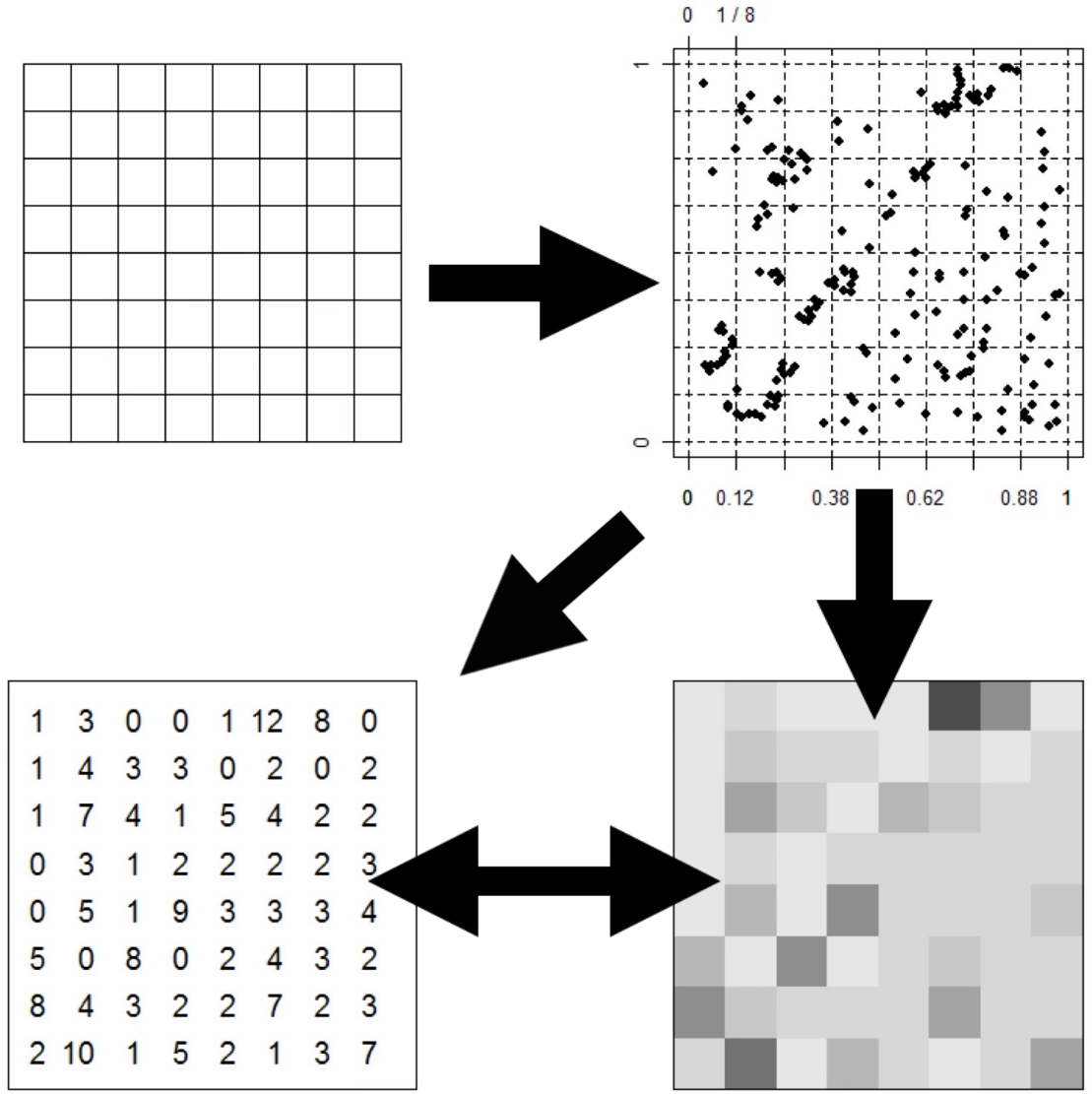


Raster



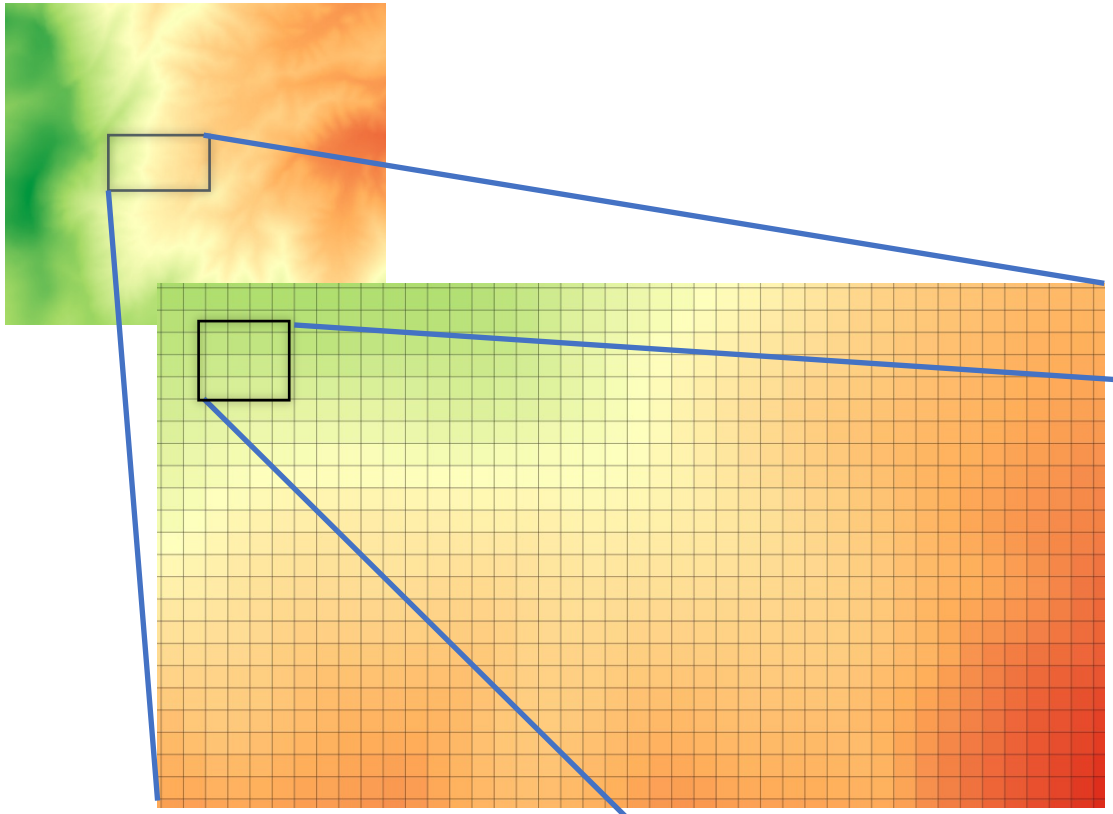
Spatial Raster Data

- Read, write and manipulate gridded spatial data
- Basic and high-level analysis functions
- Processing of large files



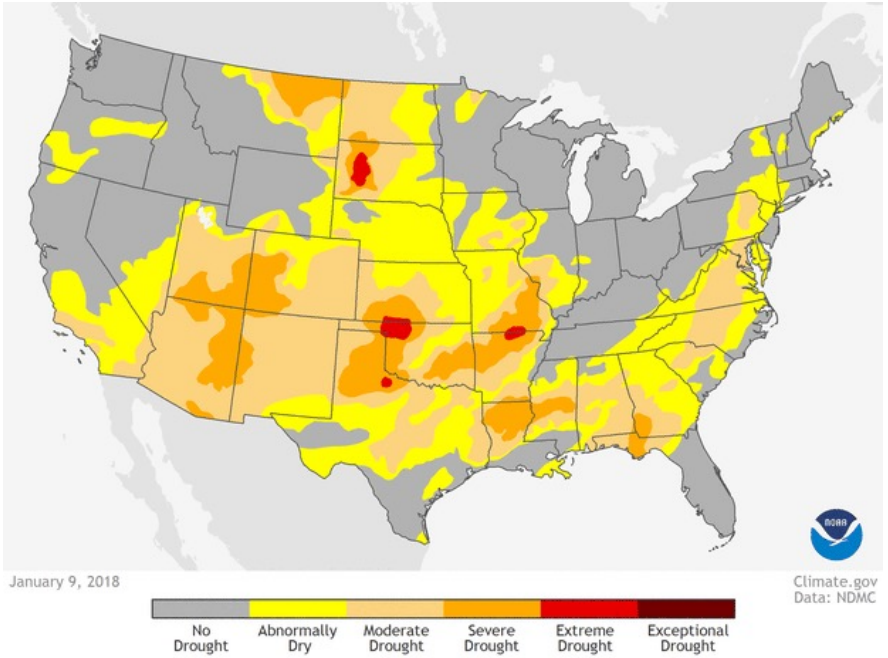
Gradients

Raster cells; each has a value



953.5	956.8	959.8	962.5	965.1	967.5
956.4	959.9	962.6	964.9	967.2	969.1
960.3	963.8	966.2	967.5	969.1	970.5
964.0	967.0	969.3	970.1	970.9	971.8
966.6	969.0	971.2	972.2	972.6	972.9
969.2	970.8	972.7	974.0	974.2	973.9

Applications

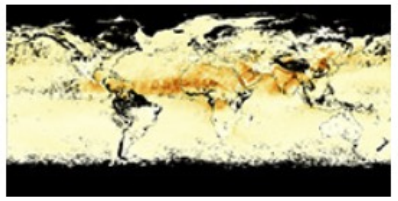


- Often more accessible to non-GIS people
  - Hazards
  - Climate
  - Environment
  - **People**
  - Terrain analysis

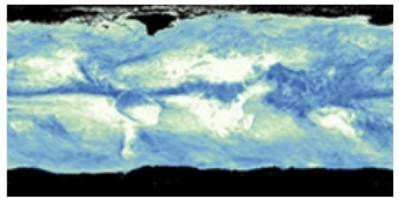
Climate

Atmosphere

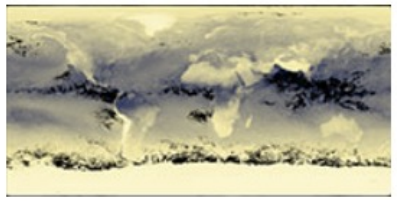
See All



Aerosol Optical Thickness



Rainfall



Water Vapor

Energy

See All

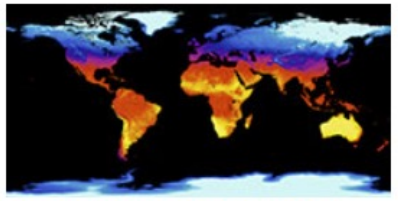
Global Temperature Anomaly

Solar Insolation

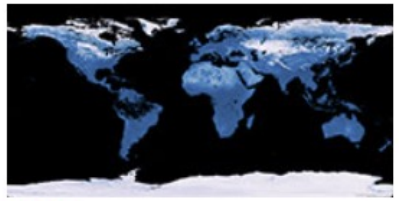
Net Radiation

Land

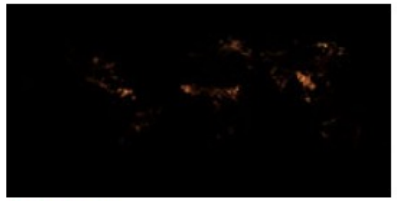
See All



Average Land Surface Temperature [Day]

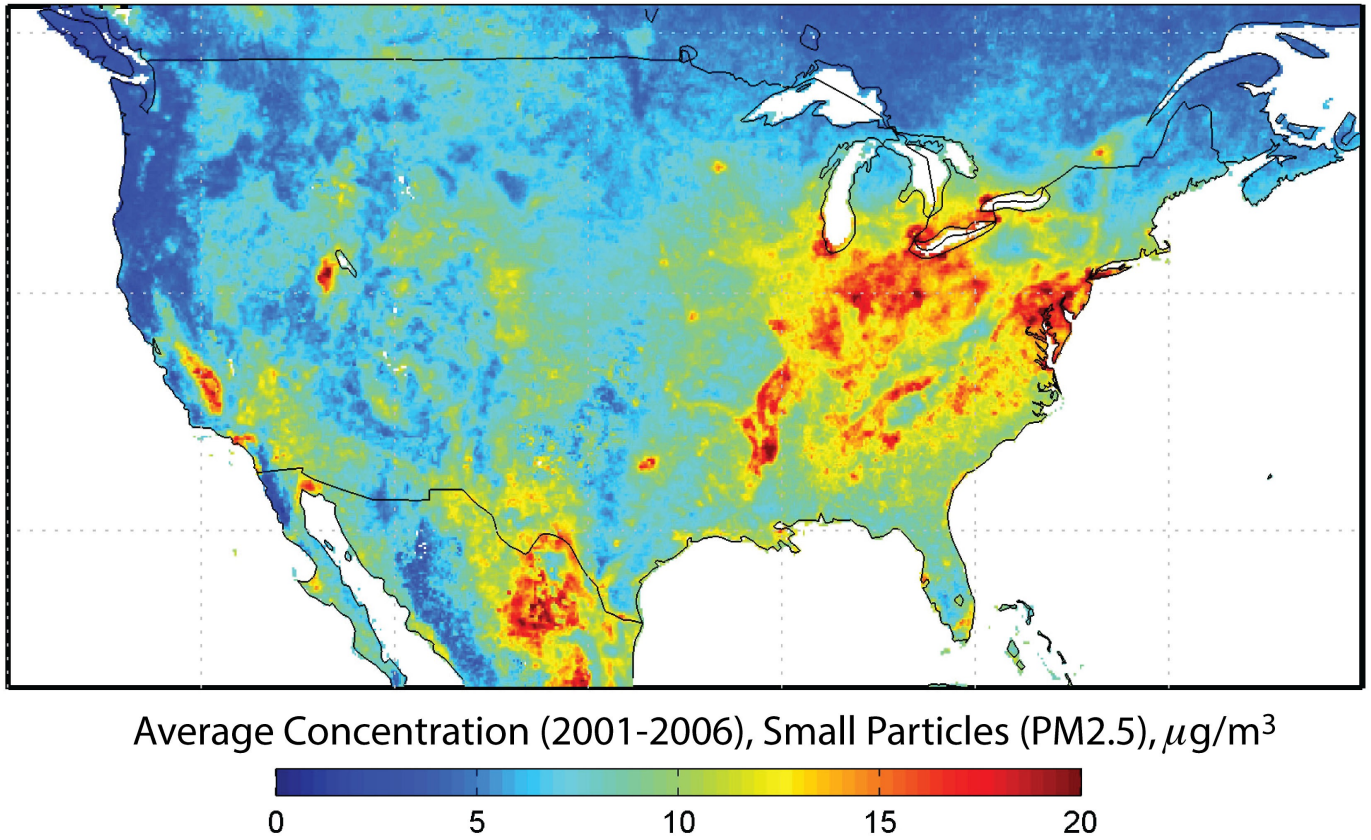


Albedo

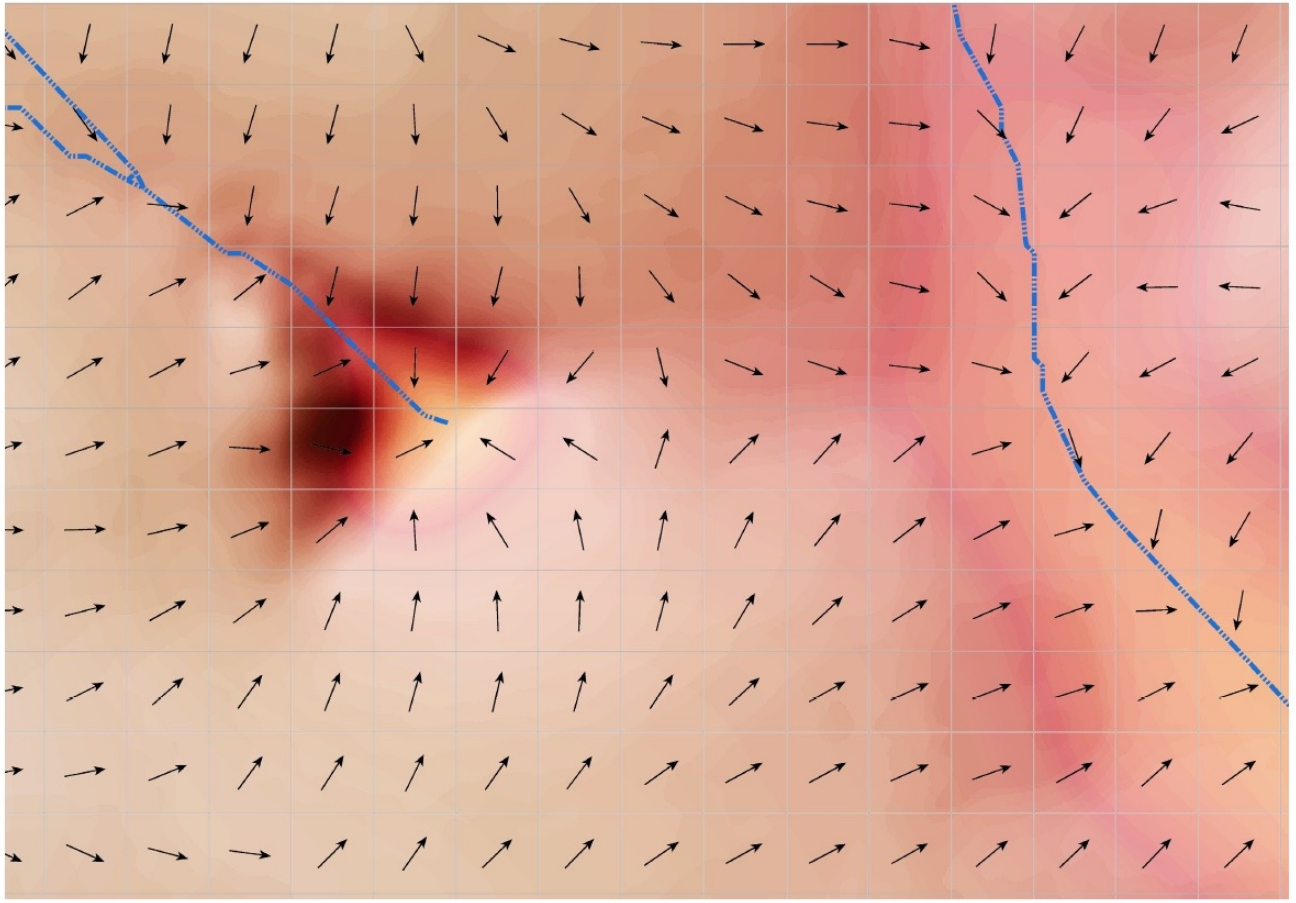


Active Fires

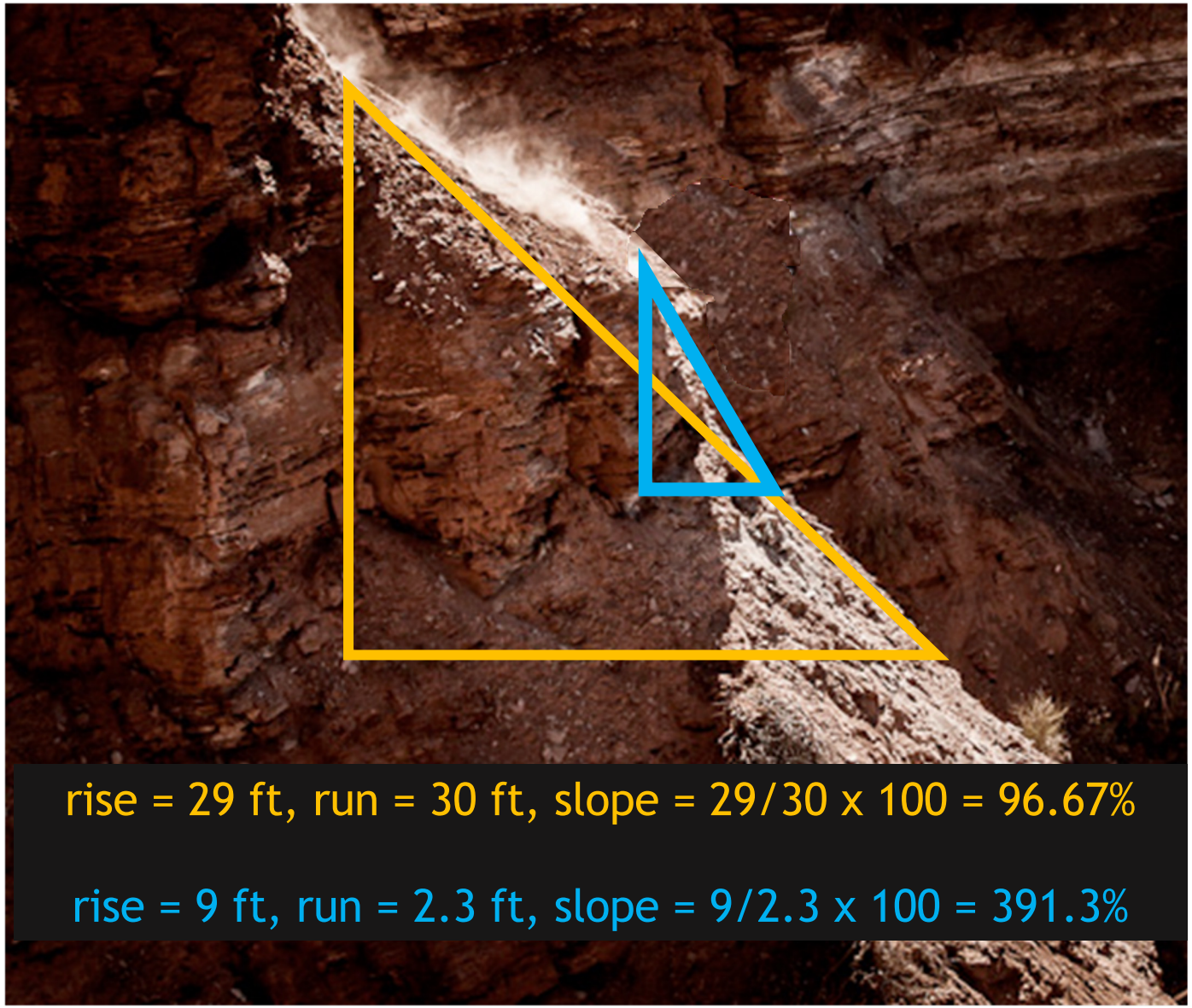
Environment



Terrain analysis



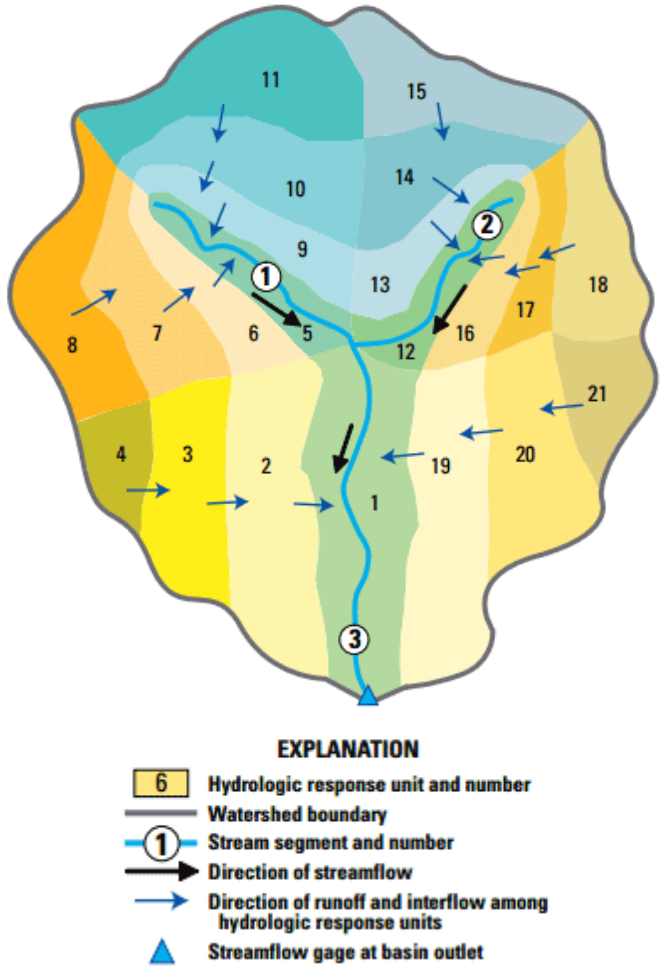
There is no “true” value in slope calculations



Slope calculations should be done in steepest direction

Watershed

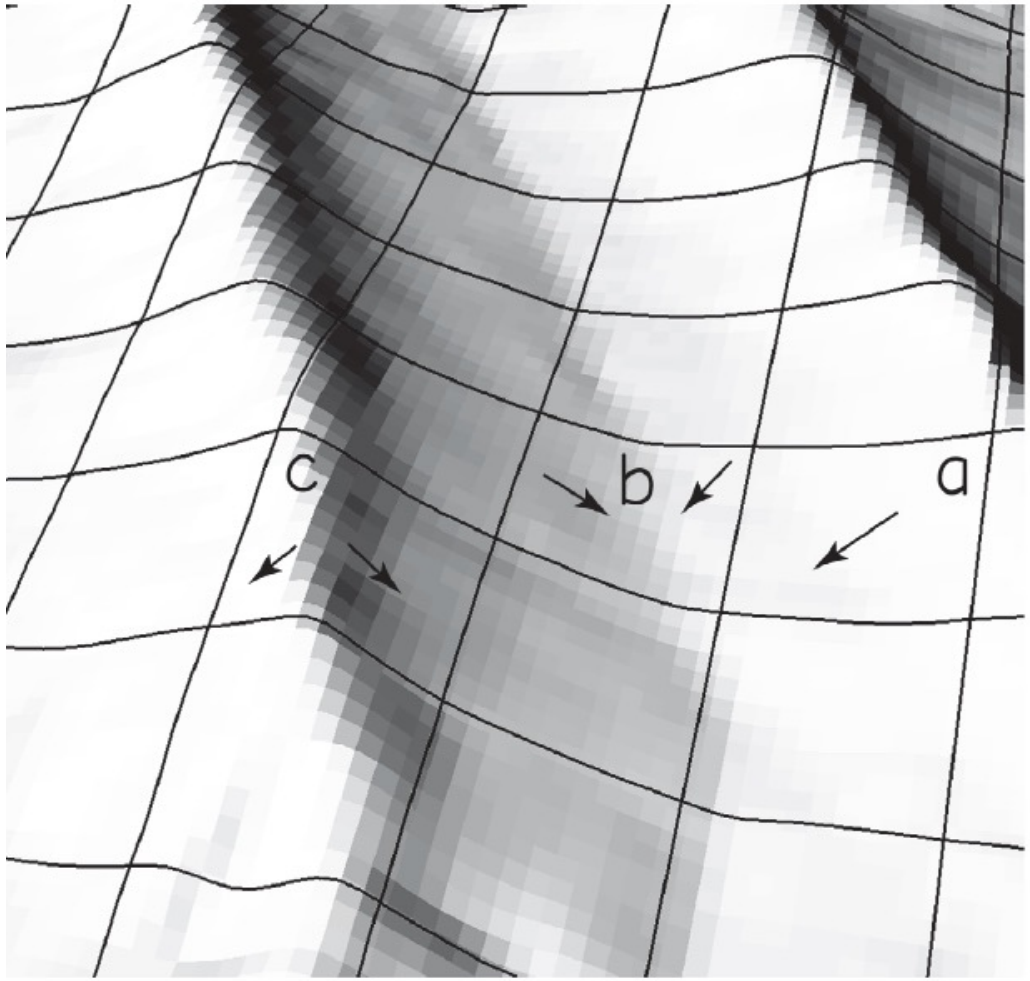
- An area that contributes flow to a point on the landscape
- Water falling anywhere in the upstream area of a watershed will pass through this “pour” point or watershed “outlet”
- Identified from a flow direction surface



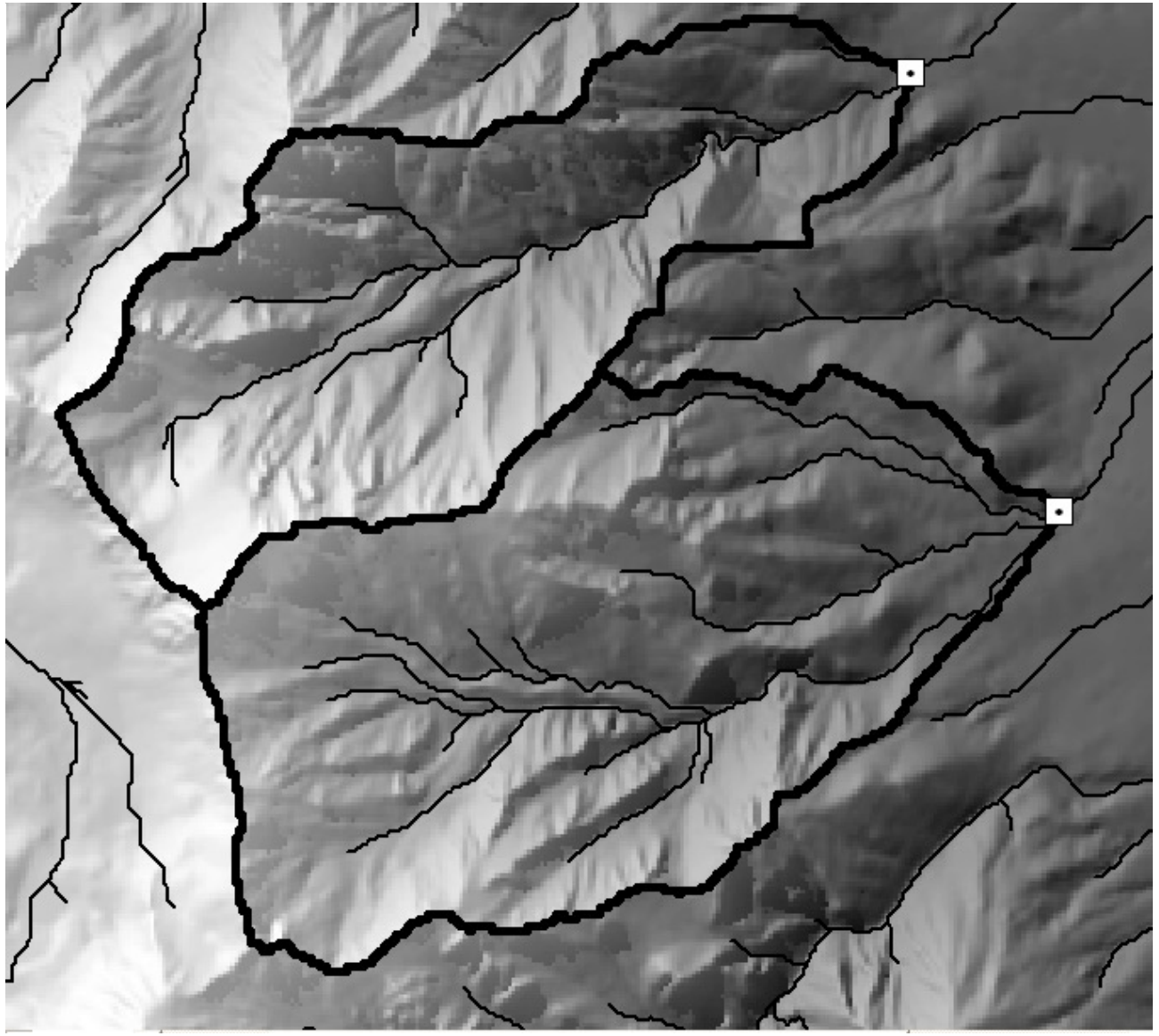
Courtesy USGS

Cell Flows:

- Simple (a)
- Convergent (b)
- Divergent (c)



Watershed
Streams
Outlets



Spatial Raster Data
Lots of Real Applications

- Raster or "gridded" data are stored as a grid of values which are rendered on a map as pixels.
- Each pixel value represents an area on the Earth's surface.

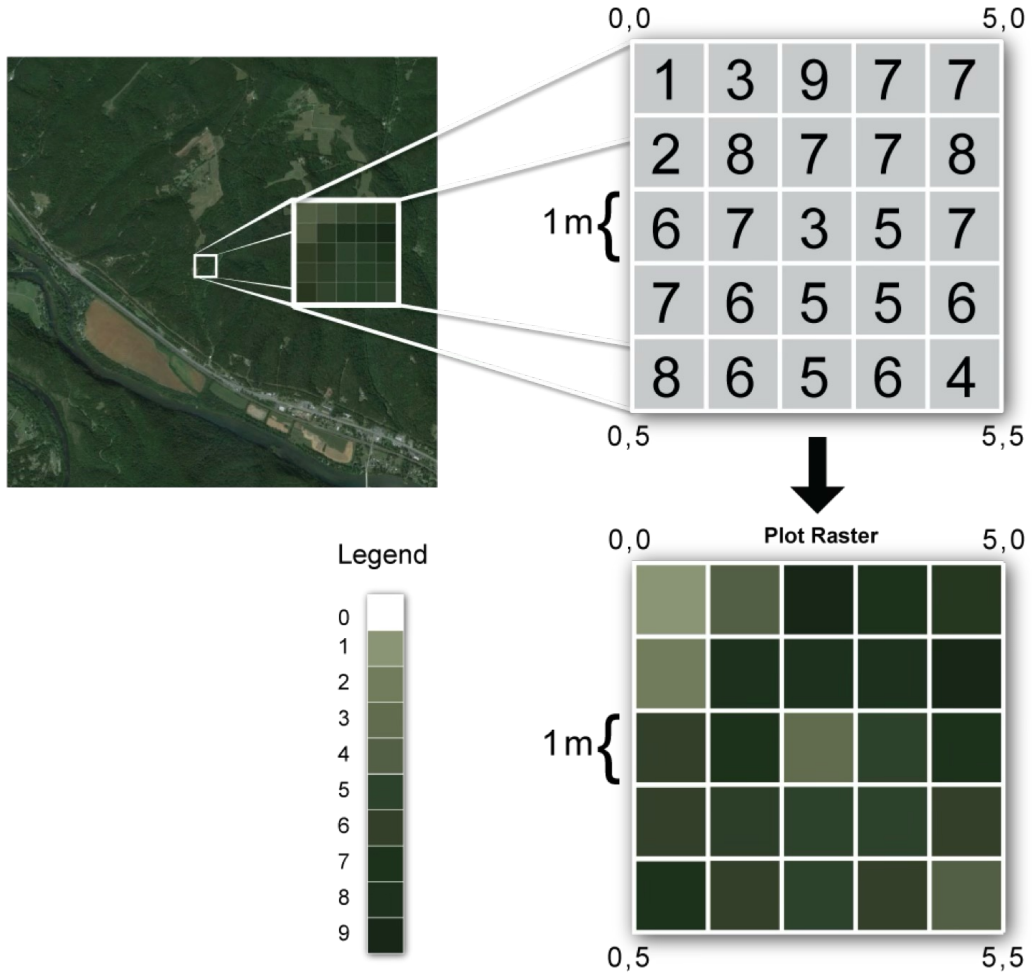


Image: National Ecological Observatory Network
https://www.neonscience.org

Spatial Raster Data Resolution

- Each pixel value represents an area on the Earth's surface
- Resolution represents the area on the ground that each pixel covers
- The best way to view resolution units is to look at the coordinate reference system string

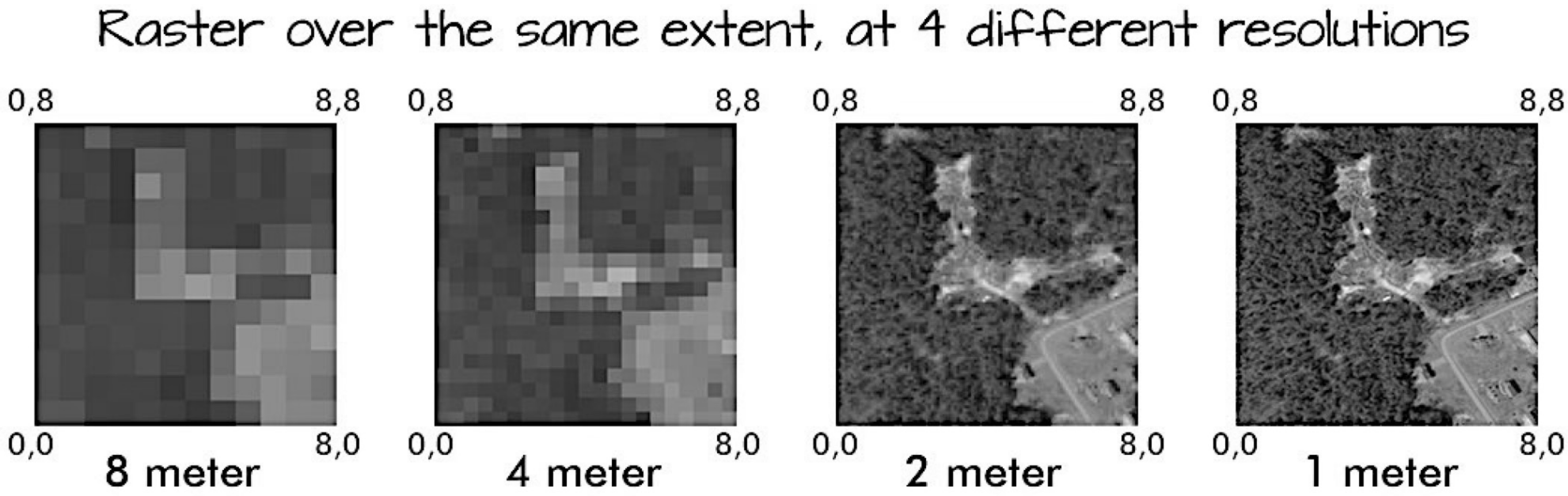
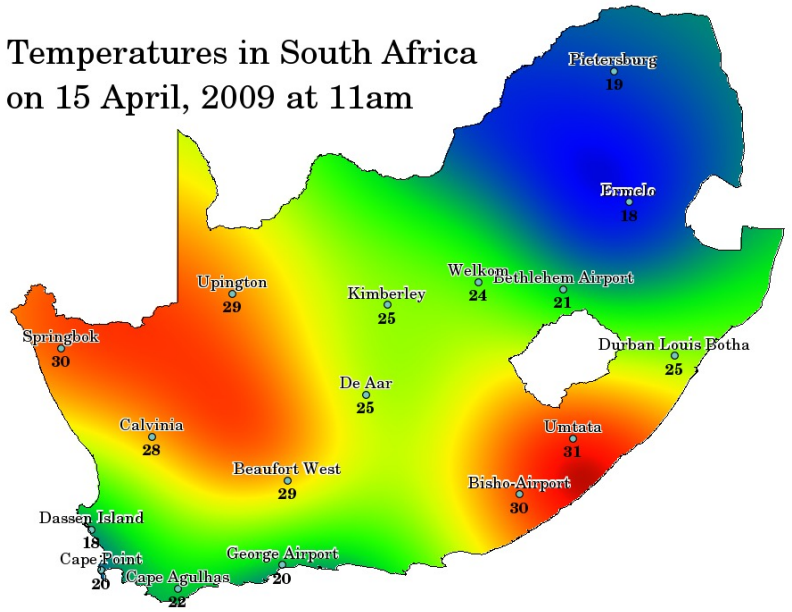
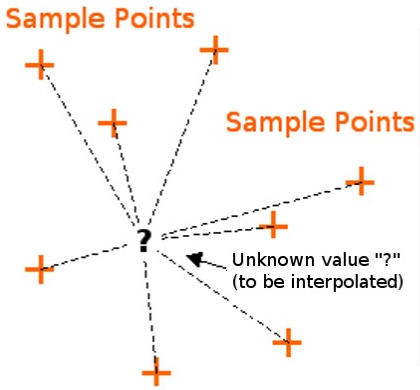
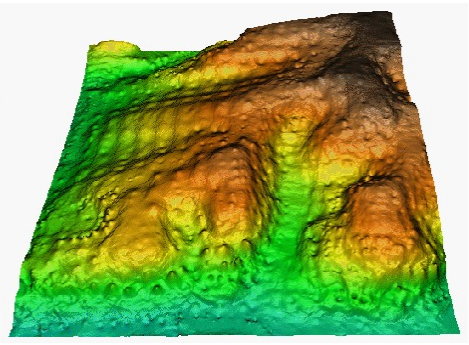


Image: National Ecological Observatory Network
https://www.neonscience.org

Interpolation







- Interpolation uses vector points with known values to estimate values at unknown locations to create a raster surface covering an entire area.
- The interpolation result is typically a raster layer.
- It is important to find a suitable interpolation method to optimally estimate values for unknown locations.
- IDW interpolation gives weights to sample points, such that the influence of one point on another declines with distance from the new point being estimated.

Spatial Raster Data

Many others geometric operations on raster data

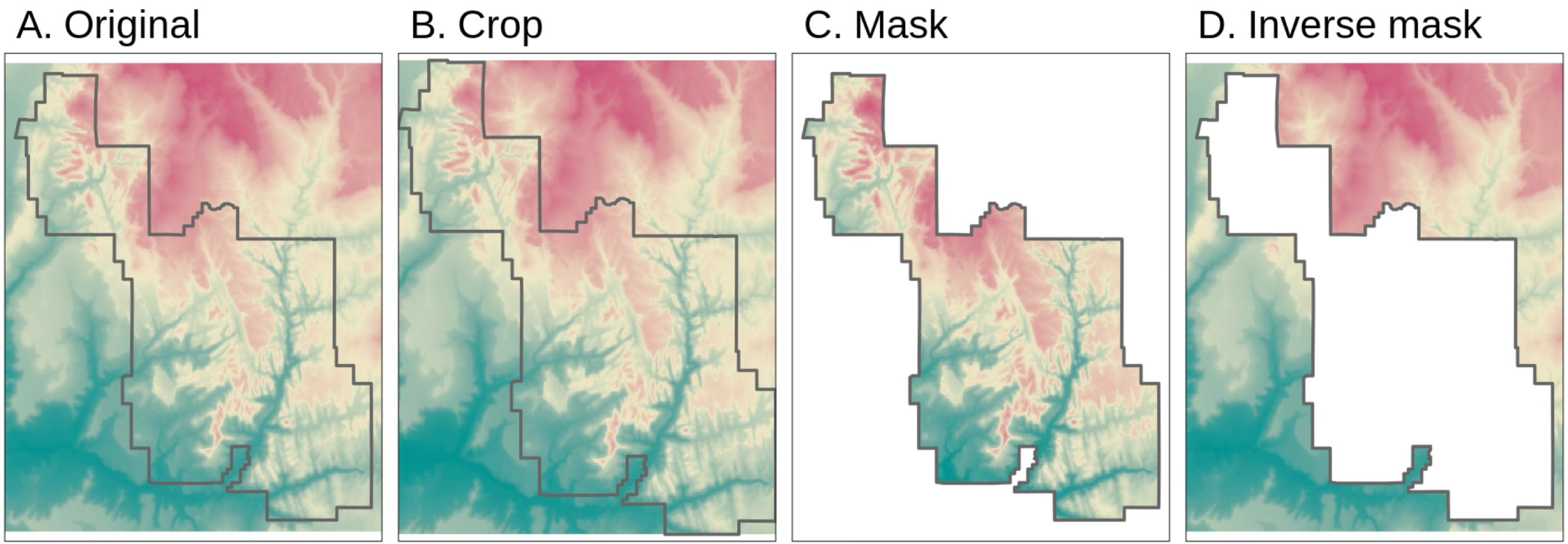
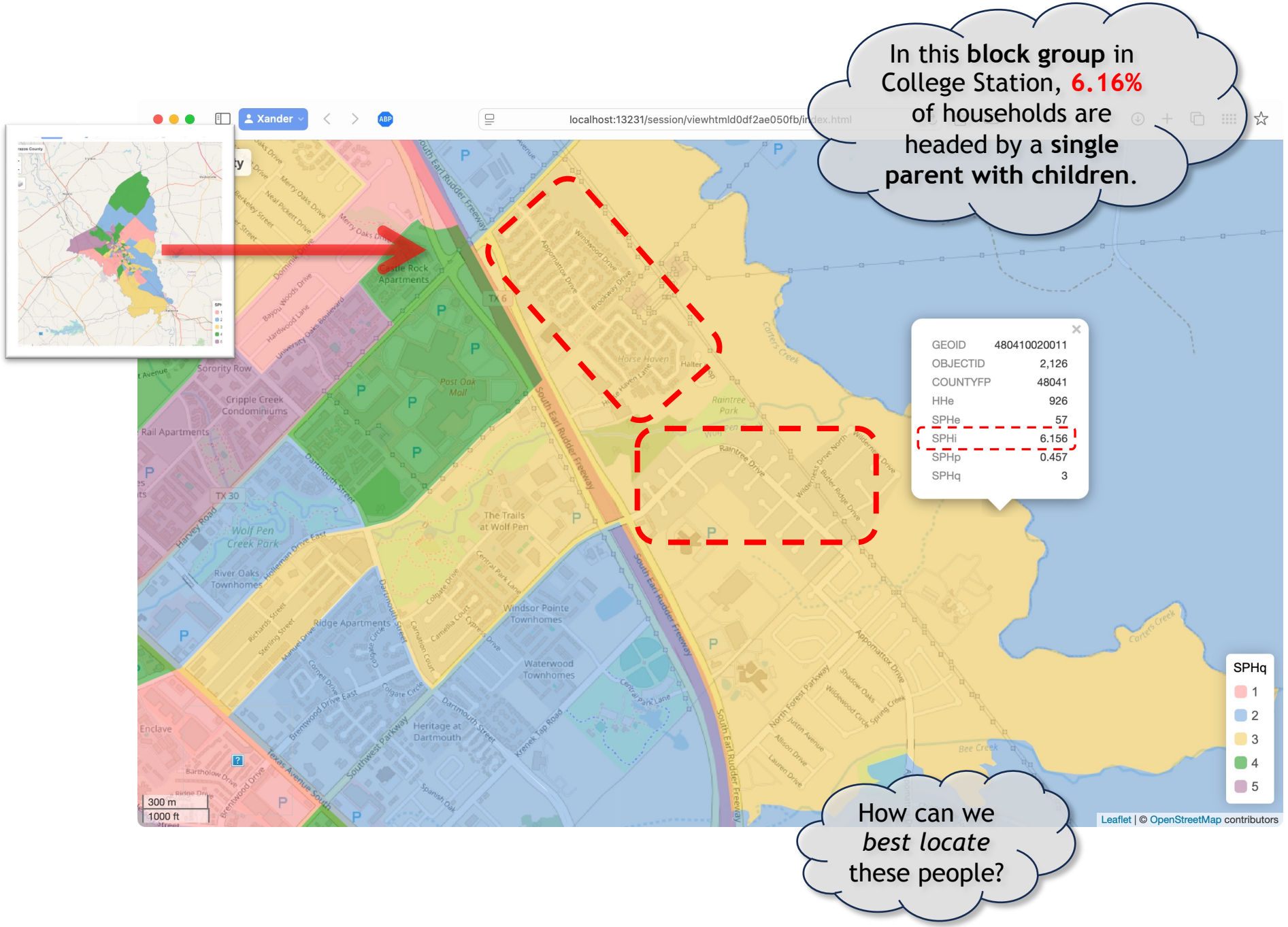


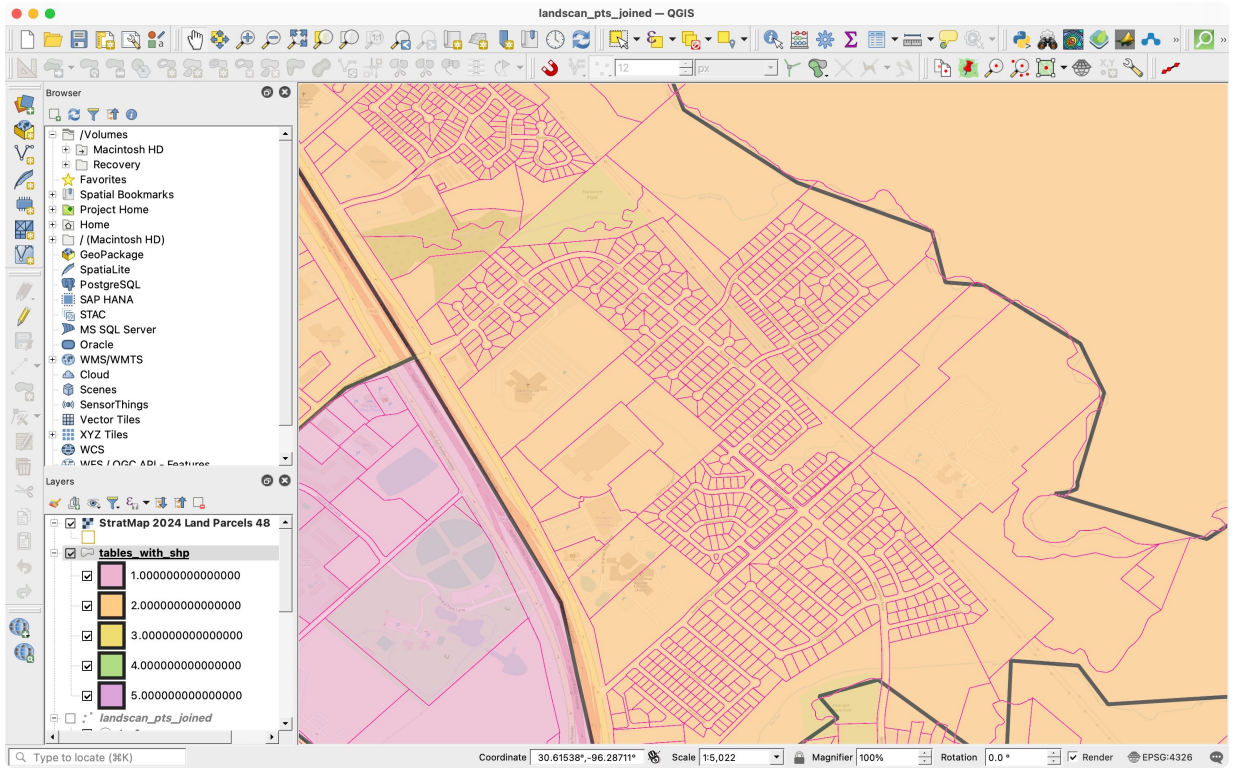
Illustration of raster cropping and raster masking

Image: Robin Lovelace, Jakub Nowosad, Jannes Muenchow


In this **block group** in College Station, 6.16% of households are headed by a **single parent with children.**
How can we *best locate* these people?
GEOID 480410020011
OBJECTID 2,126
COUNTYFP 48041
HHe 926
SPHe 57
SPHi 6.156
SPHp 0.457
SPHq 3
SPHq
1
2
3
4
5
Leaflet | © OpenStreetMap contributors
300 m
1000 ft

Option 1:

parcels

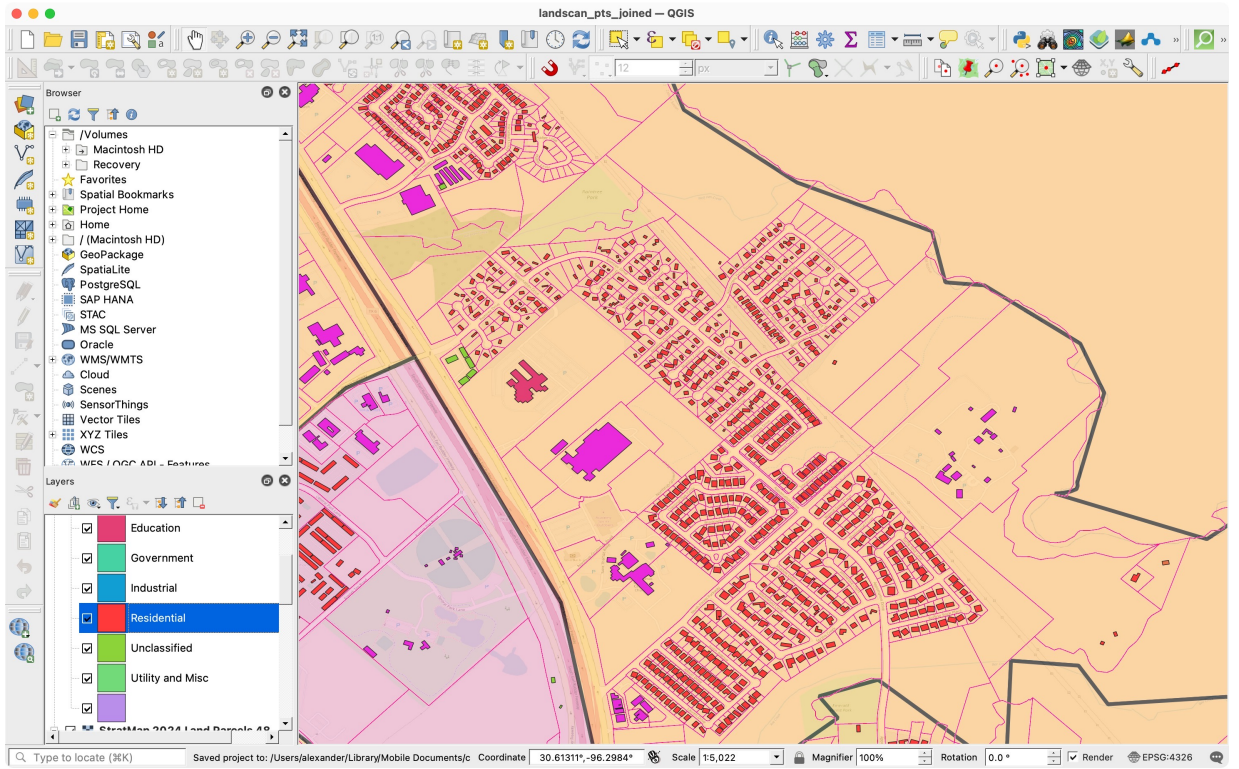


https://brazoscad.org/gis/

- Parcel mapping standards vary across counties.
- Each county may have its own zoning code, land use type.
- Data not always available, leading to inconsistencies.

Option 2:

parcels + **buildings footprint**

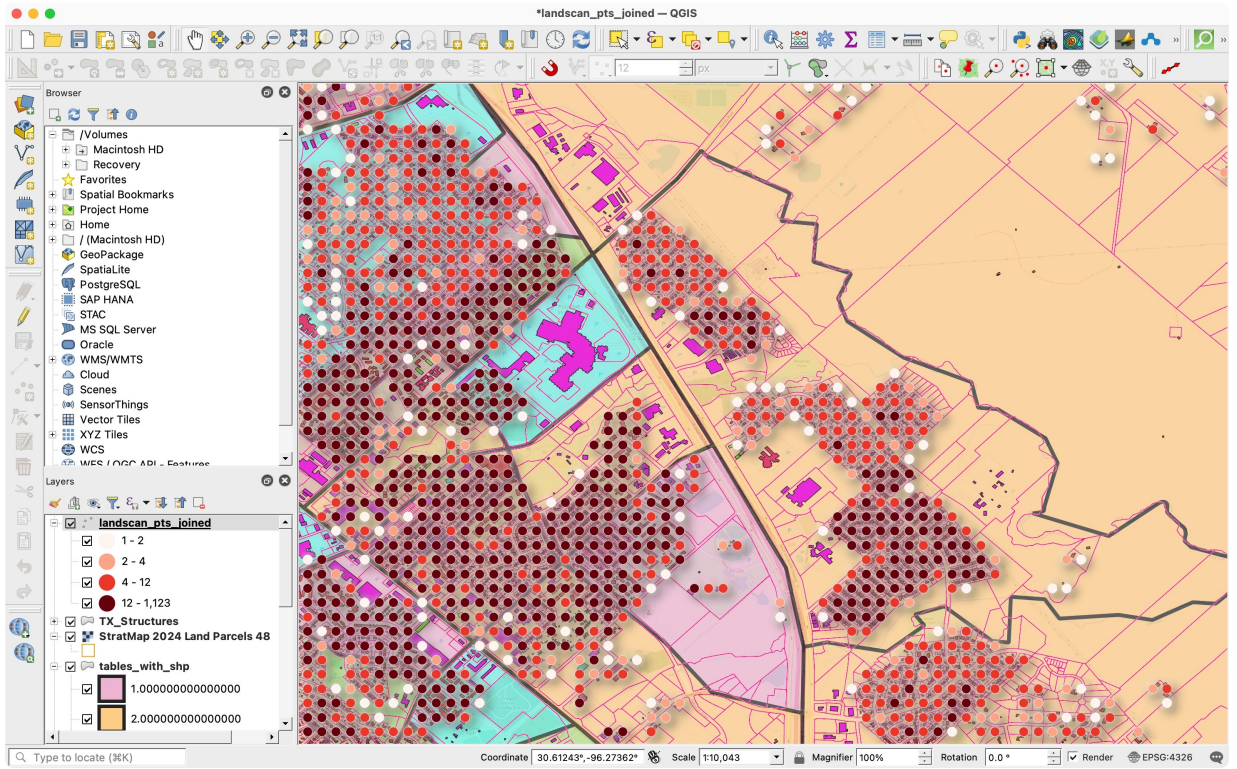


https://disasters.geoplatform.gov/USA_Structures/

- New dataset, still with inconsistent building classifications.
- Still very dependent on good imageries.
- Difficulty in allocating the number of people bc they are not necessarily related to the building footprint.

Option 3:

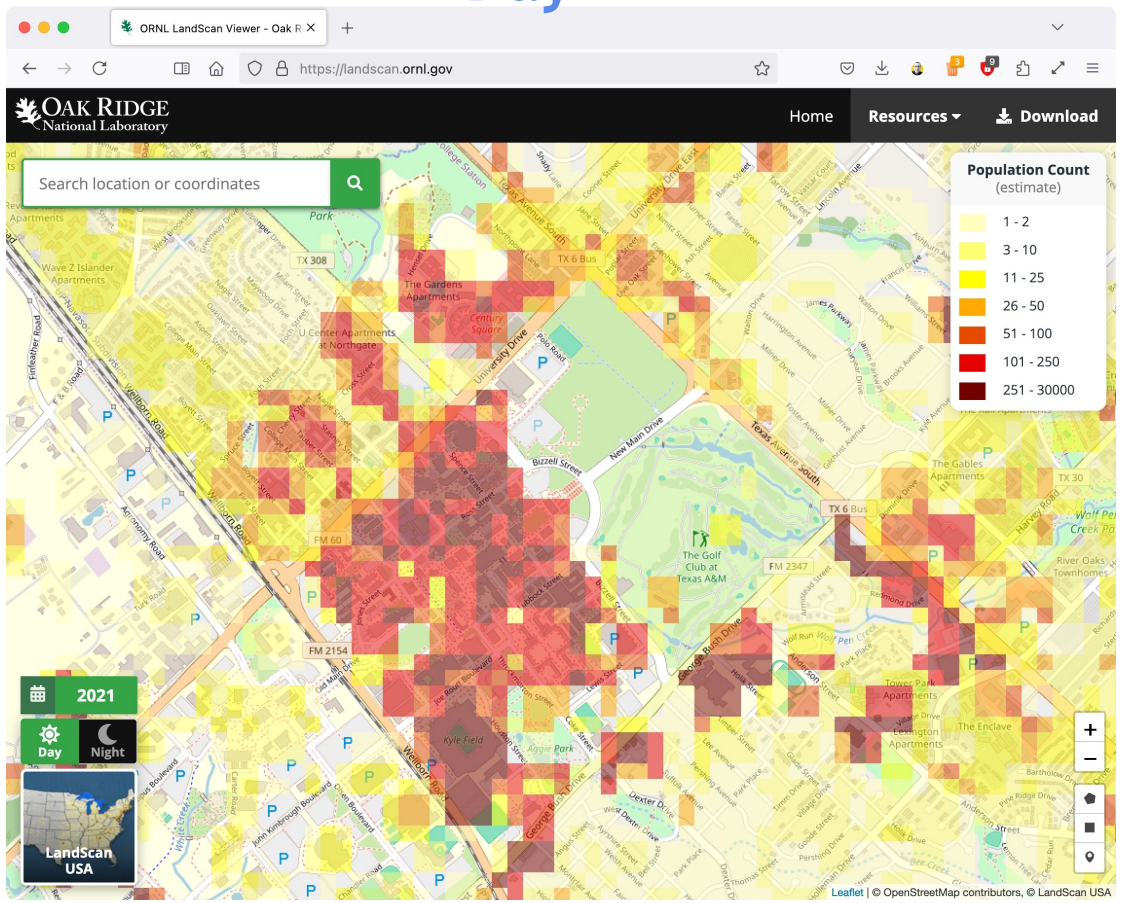
parcels + buildings footprint + **population distribution**

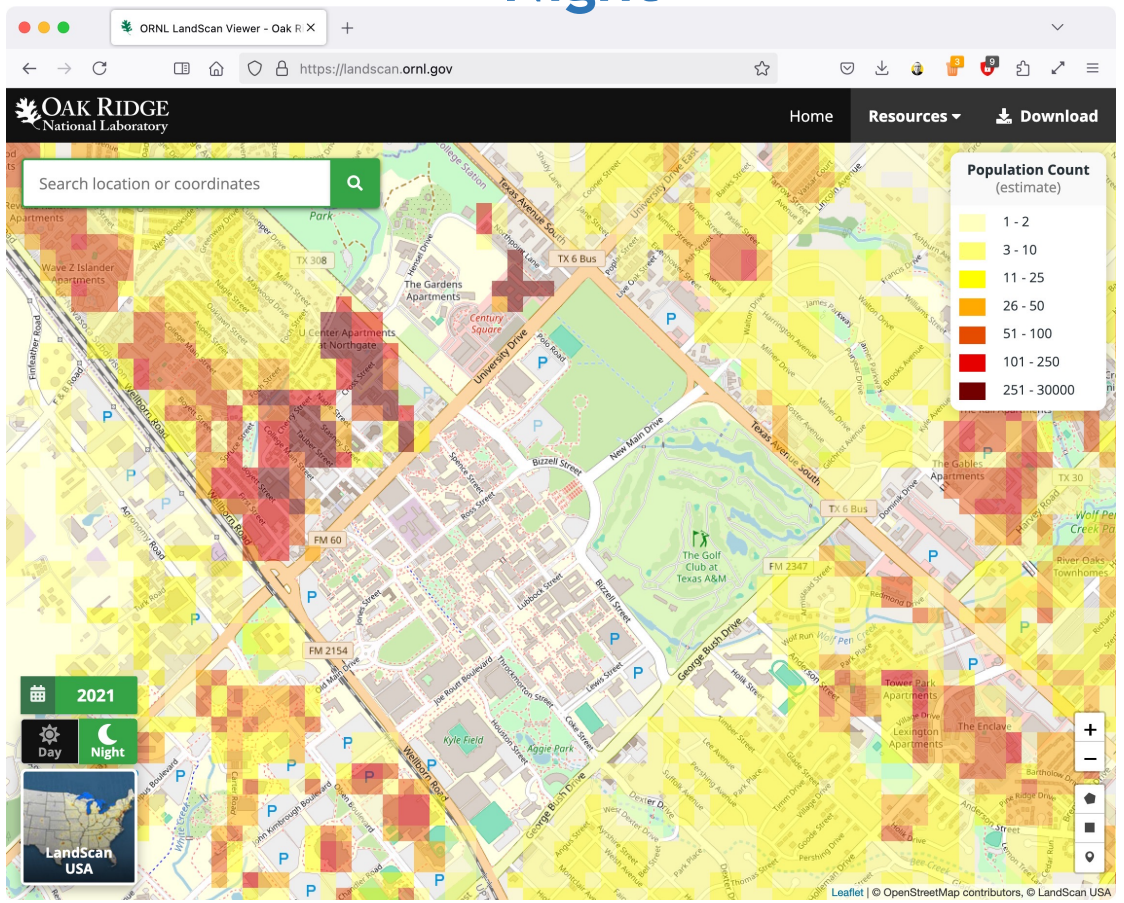


https://landscan.ornl.gov

Day

Night


ORNL LandScan Viewer - Oak R
https://landscan.ornl.gov
OAK RIDGE National Laboratory
Home
Resources
Download
Search location or coordinates
Population Count
(estimate)
1 - 2
3 - 10
11 - 25
26 - 50
51 - 100
101 - 250
251 - 30000
2021
Day
Night
LandScan USA
Leaflet | © OpenStreetMap contributors, © LandScan USA


ORNL LandScan Viewer - Oak R
https://landscan.ornl.gov
OAK RIDGE National Laboratory
Home
Resources
Download
Search location or coordinates
Population Count
(estimate)
1 - 2
3 - 10
11 - 25
26 - 50
51 - 100
101 - 250
251 - 30000
2021
Day
Night
LandScan USA
Leaflet | © OpenStreetMap contributors, © LandScan USA

Introduction for the Practice

Hazard risk investigation

- We will briefly analyze *parcel data* (dwelling lots) in the Brazos County to find ones in risk of inundation due to be in a flood risk area
- Annual chance is the flood that has an annual chance of being equaled or exceeded in any year

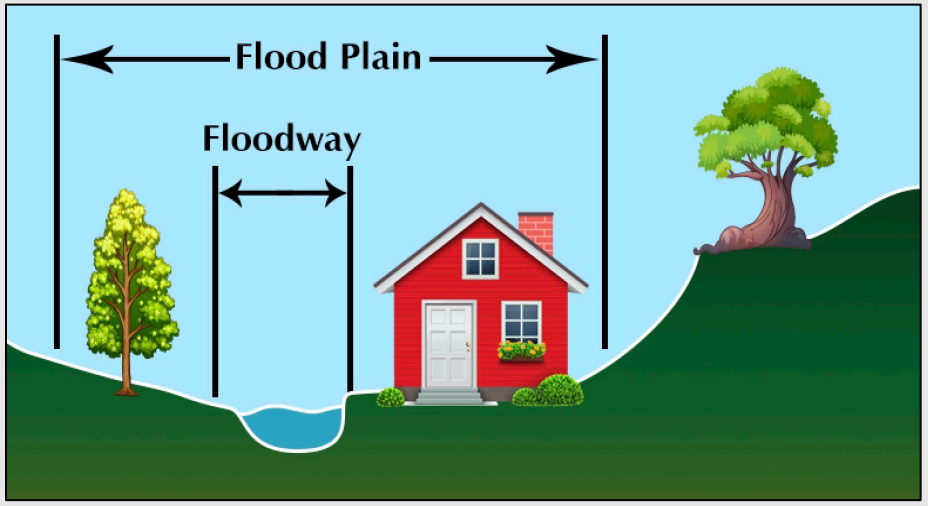
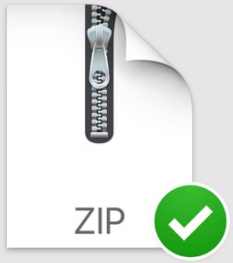


Image source: http://www.sjra.net/about/facts/what-is-a-flood-plain/

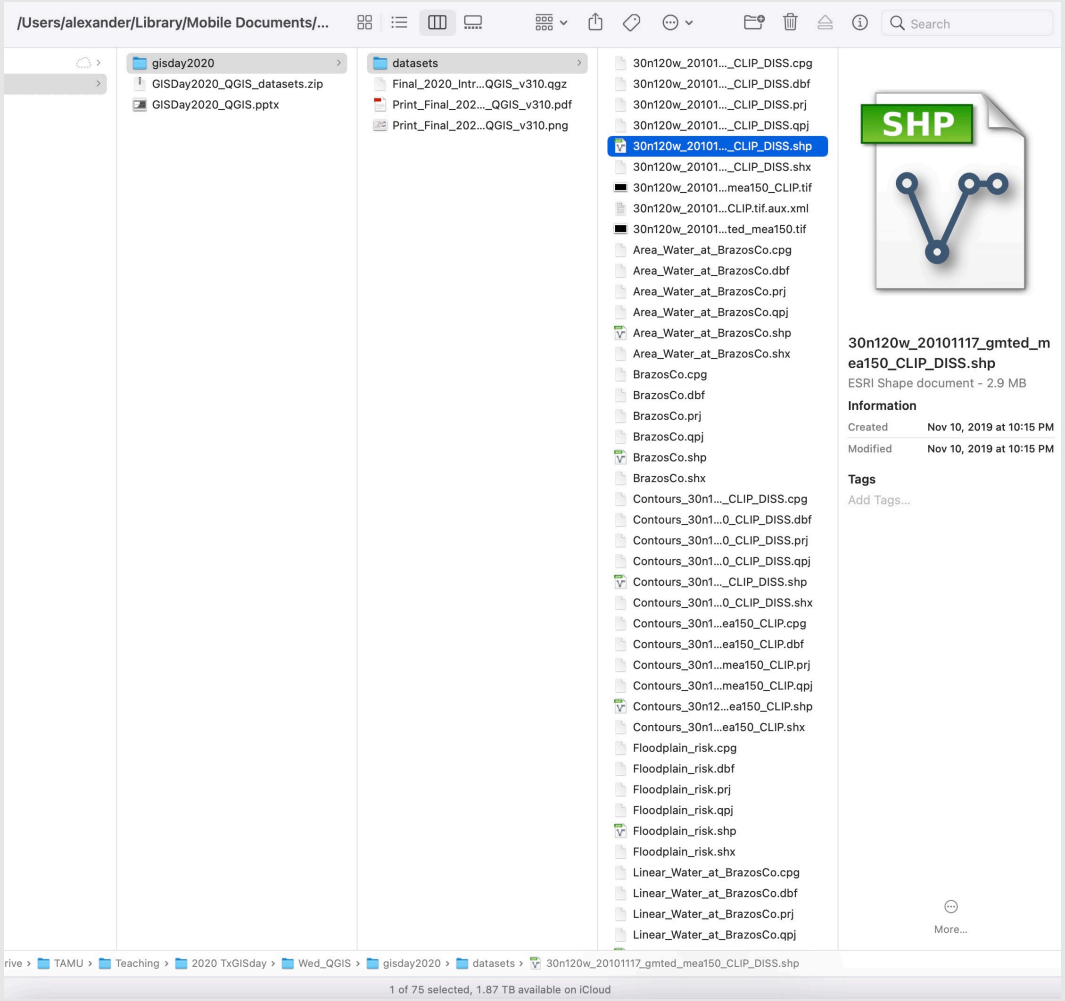
- The primary risk classifications we will used are:
  - the 1-percent-annual-chance flood event → 100-Year floodplain
  - the .2-percent-annual-chance flood event → 500-Year floodplain
  - and areas of minimal flood risk → Out of the floodplain

Data Acquisition

1. Download the **datasets.zip** at
https://github.com/abuabara/txgisday2025



2. Unzip it



3. Save in a work folder.

PS. Source for the original datasets are in the last slide of the presentation!

Shapefile format (vector)

“Shapefile” really is a set of files sharing a common *basename*.

The extension indicates which part of the information each file carries.

.dbf (the data table part, editable in dBase, R, Stata, etc)

.prj (the CRS i.e., map projection info)

.shp (the geometric part)

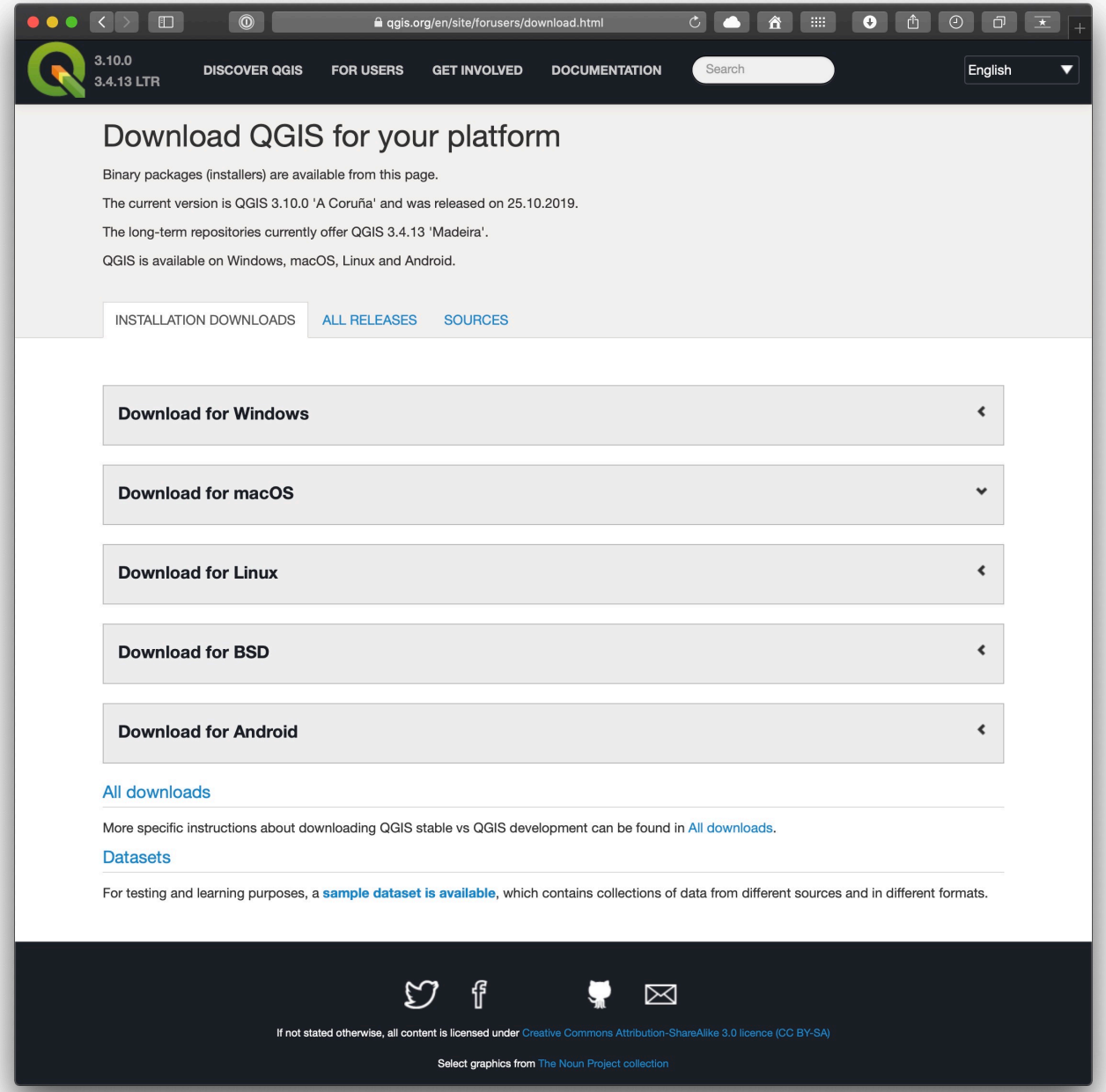
.shx (an index linking the dbf+shp parts)

Raster format (image)

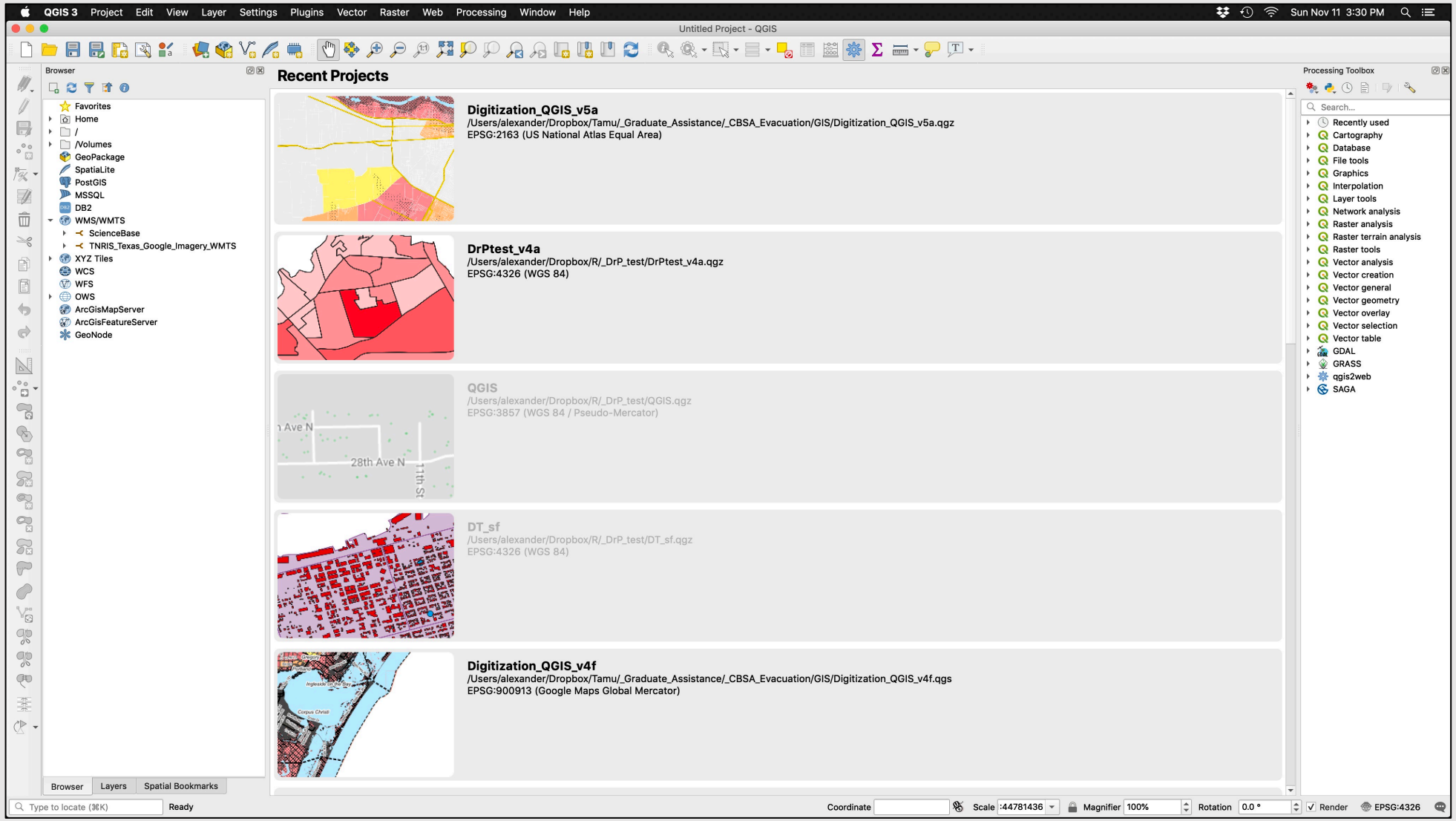
GIS data is commonly stored in a raster format to encode geographic data as the pixel values. Georeferencing information can also be associated with pixels!

QGIS installation

QGIS after v3.4 will automatically install Python, GDAL, PROJ.4, and GRASS framework dependencies



Interface



right-click in the toolbar

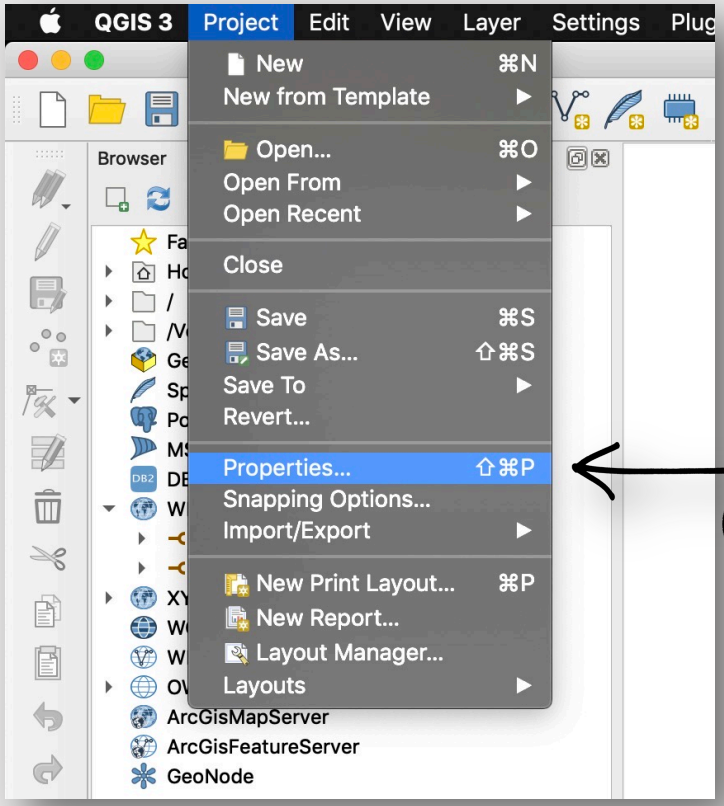
Panels

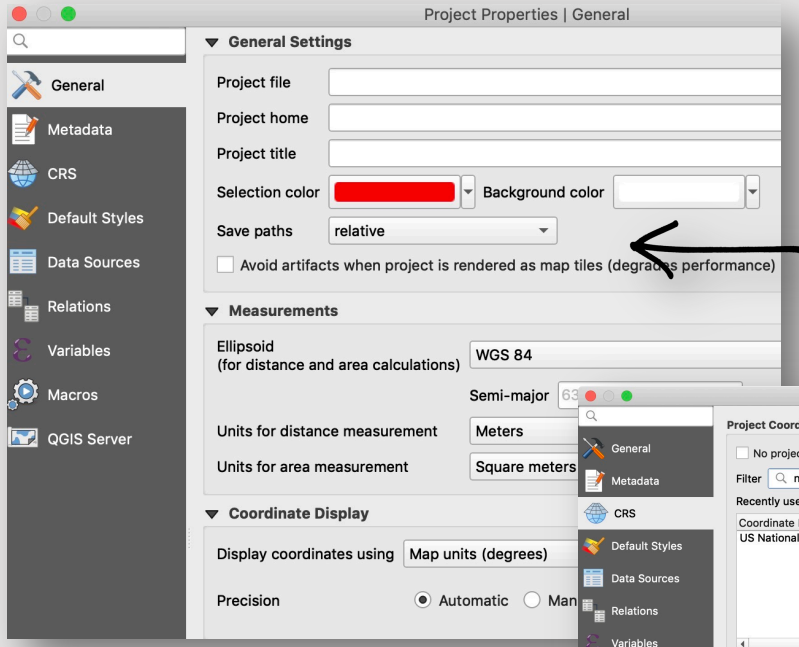
- [ ] Advanced Digitizing Panel
- [ ] Browser (2) Panel
- [x] Browser Panel
- [ ] GPS Information Panel
- [ ] Layer Order Panel
- [ ] Layer Styling Panel
- [x] Layers Panel
- [ ] Log Messages Panel
- [ ] Overview Panel
- [x] Processing Toolbox Panel
- [ ] Results Viewer Panel
- [ ] Search QMS Panel
- [x] Spatial Bookmarks Panel
- [ ] Statistics Panel
- [ ] Tile Scale Panel
- [ ] Undo/Redo Panel

Toolbars

- [x] Advanced Digitizing Toolbar
- [x] Attributes Toolbar
- [ ] CartoLineGen
- [x] Data Source Manager Toolbar
- [ ] Database Toolbar
- [x] Digitizing Toolbar
- [ ] Help Toolbar
- [ ] Label Toolbar
- [ ] Manage Layers Toolbar
- [x] Map Navigation Toolbar
- [ ] Plugins Toolbar
- [x] Project Toolbar
- [ ] QuickOSM
- [ ] Raster Toolbar
- [ ] Shape Digitizing Toolbar
- [ ] Snapping Toolbar
- [x] Vector Toolbar
- [ ] Web Toolbar

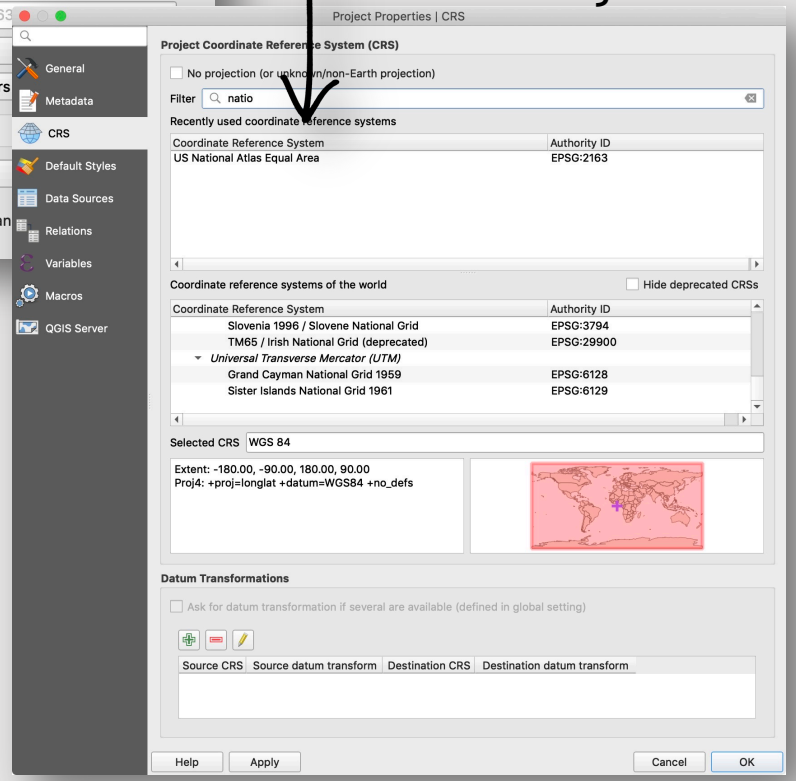
Project set-up





Relative paths!

Projection!



Projection

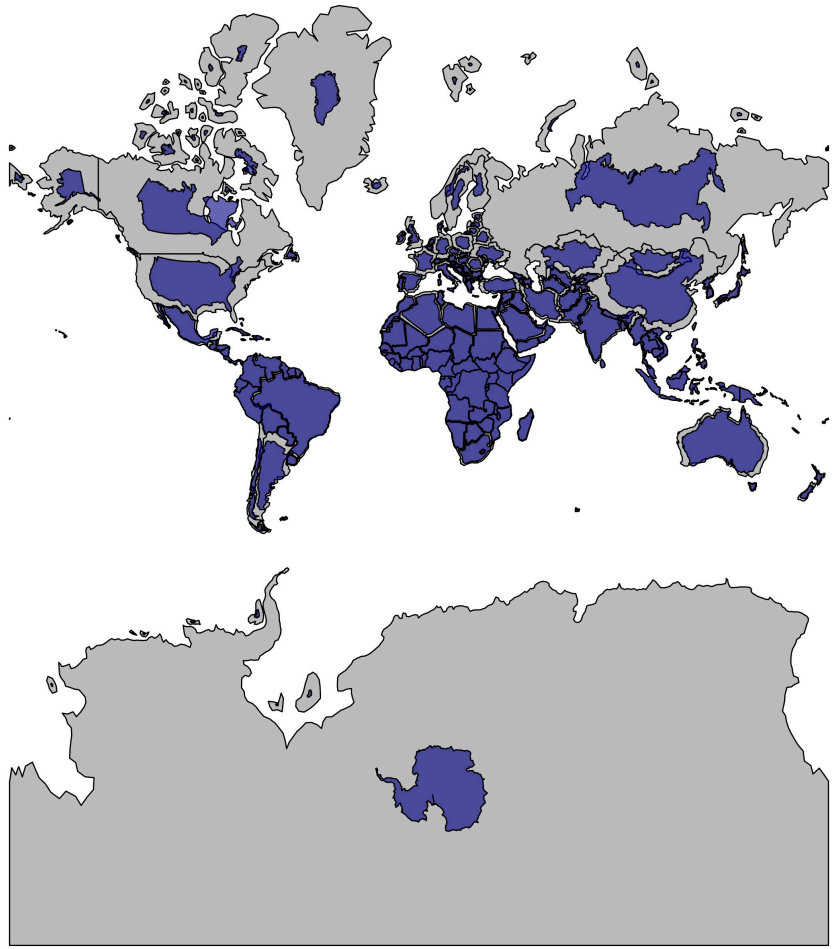
Map projections can be deceptive!

ESPG:4326 (WGS84/Mercator) x True size

We will use:

Lambert Azimuthal Equal Area: US National Atlas EPSG:2163

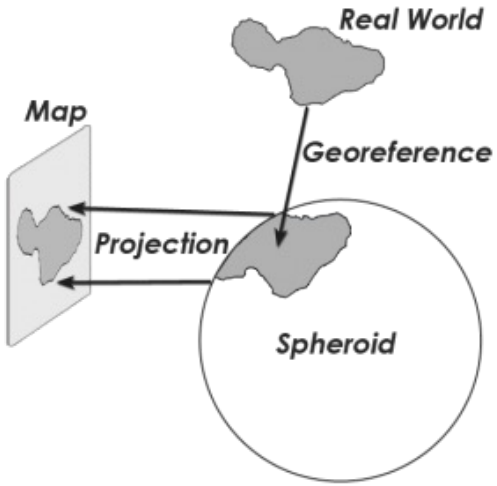
https://epsg.io/2163



Source code can be found here:
https://twitter.com/neilrkaye/status/1050722881657864192

Coordinate Reference Systems (CRSs)

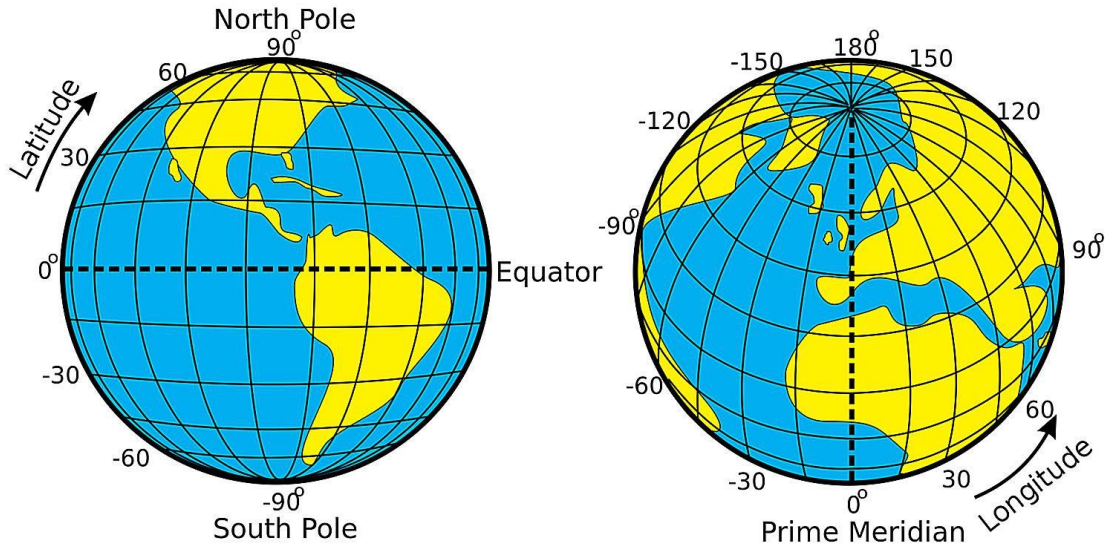
- CRSs are essential for spatial data, defining how spatial elements correspond to the Earth's surface.



- Types of CRSs:
  - **Geographic CRSs:**
    - Represent data on a **three-dimensional surface** (e.g., latitude and longitude).
    - Coordinate units are typically **degrees**.
  - **Projected CRSs:**
    - Represent data on a **two-dimensional**, flat plane.
    - Transform spherical Earth data into a **flat map**.
    - Coordinate units can be in **meters**, **feet**, etc.

Coordinate Reference Systems

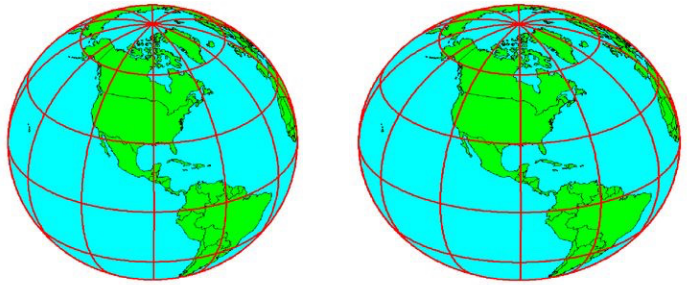
Geographic Coordinate Reference Systems



- Geographic CRSs use longitude and latitude to identify locations on Earth.
  - **Longitude**: Measures East-West position relative to the Prime Meridian.
  - **Latitude**: Measures North-South position relative to the equatorial plane.
  - Distances are measured in **angular units** (degrees), not meters, impacting spatial measurements.

Coordinate Reference Systems

Geographic Coordinate Reference Systems

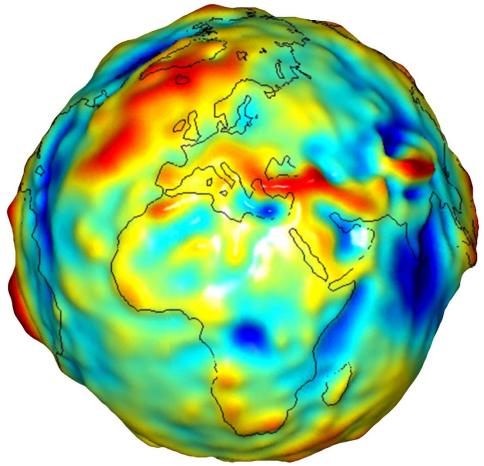


a b

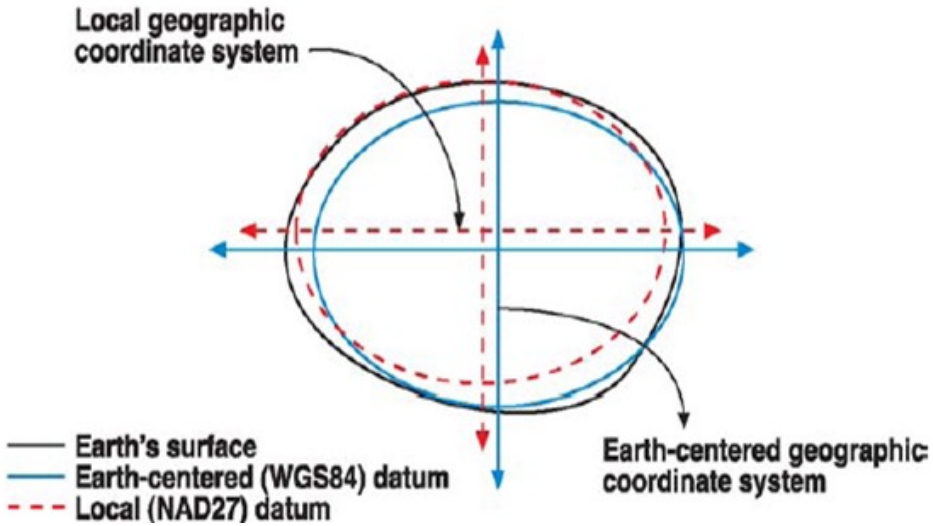
- The Earth can be modeled as spherical or ellipsoidal.
  - **Spherical models** (a): Simplify calculations by assuming Earth is a perfect sphere.
  - **Ellipsoidal models** (b): More accurately represent Earth with distinct equatorial and polar radii. The equatorial radius is about 11.5 km longer than the polar radius due to Earth's compression.

Coordinate Reference Systems

Geographic Coordinate Reference Systems

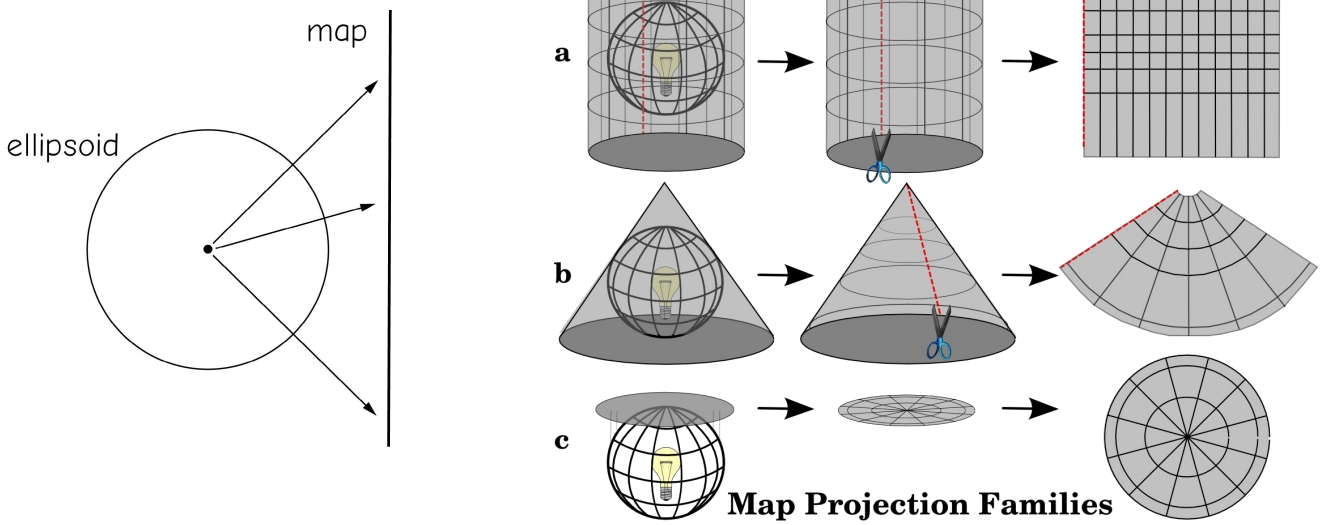


Geoidal heights

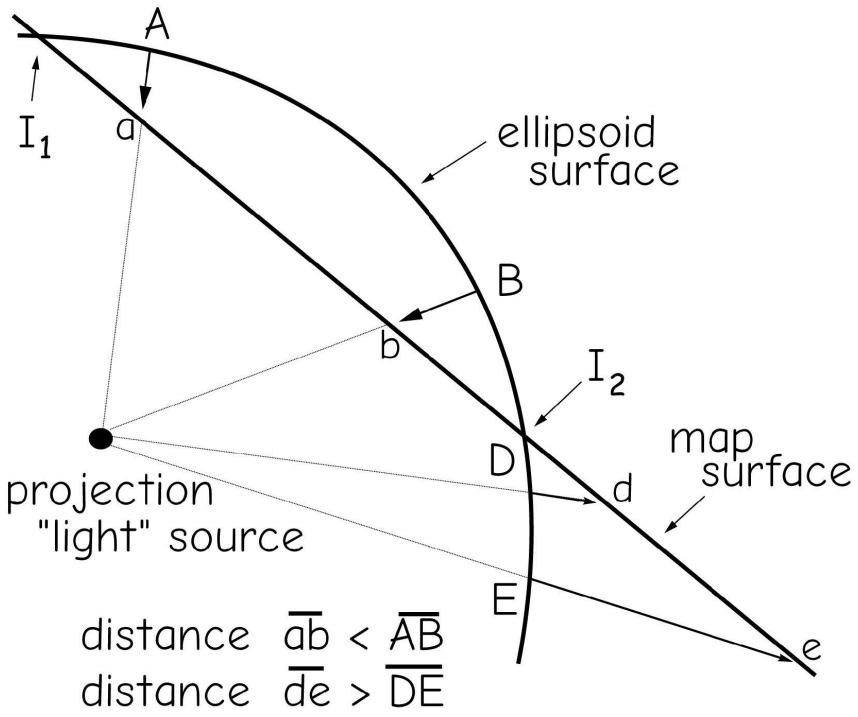


- The two types of Datums are:
  - **Geocentric datum** (e.g., WGS84): Centered at Earth's center of gravity, providing global consistency but less local accuracy.
  - **Local datum** (e.g., NAD83): Adjusted for specific regions to better align with the Earth's surface, accounting for local geographic variations (e.g., mountain ranges).

Types of Projections and Their Characteristics



Type of Projection	Description	Common Properties Preserved	Best Used For
Cylindrical (a)	Projects Earth's surface onto a cylinder.	Direction, shape	World maps
Conic (b)	Projects Earth's surface onto a cone.	Area, shape	Maps of mid-latitude regions
Planar (Azimuthal) (c)	Projects onto a flat surface at a point or line.	Distance, direction	Polar region maps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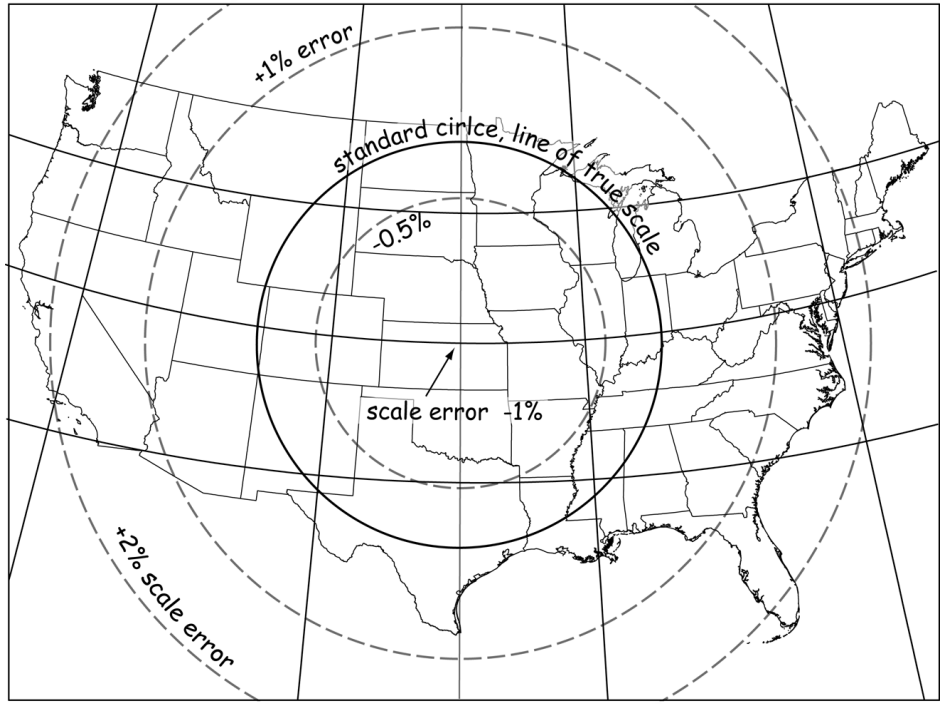
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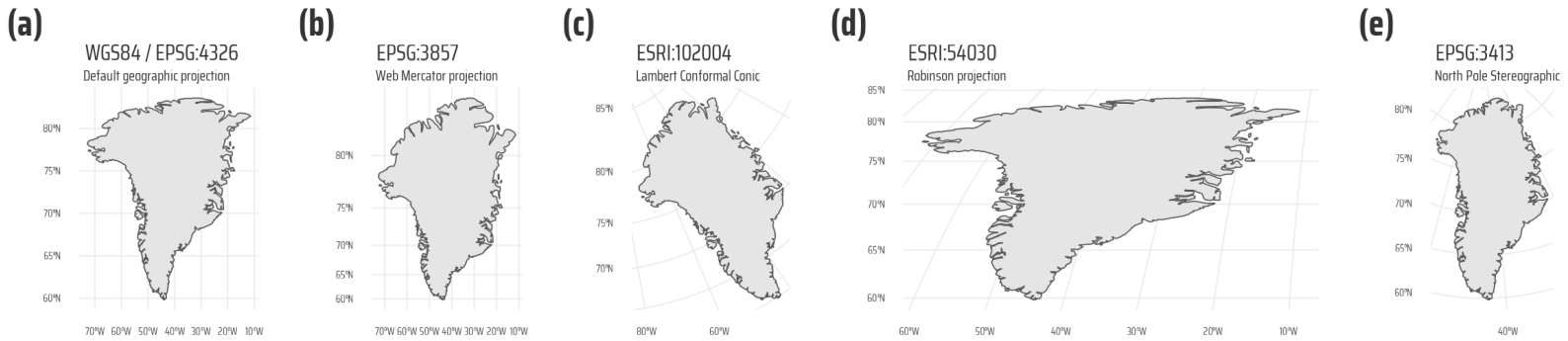
standard cirlce, line of true scale
-0.5%
scale error -1%
+2% scale error

Deformations by Projection Type

Check the map projection explorer: https://www.geo-projections.com

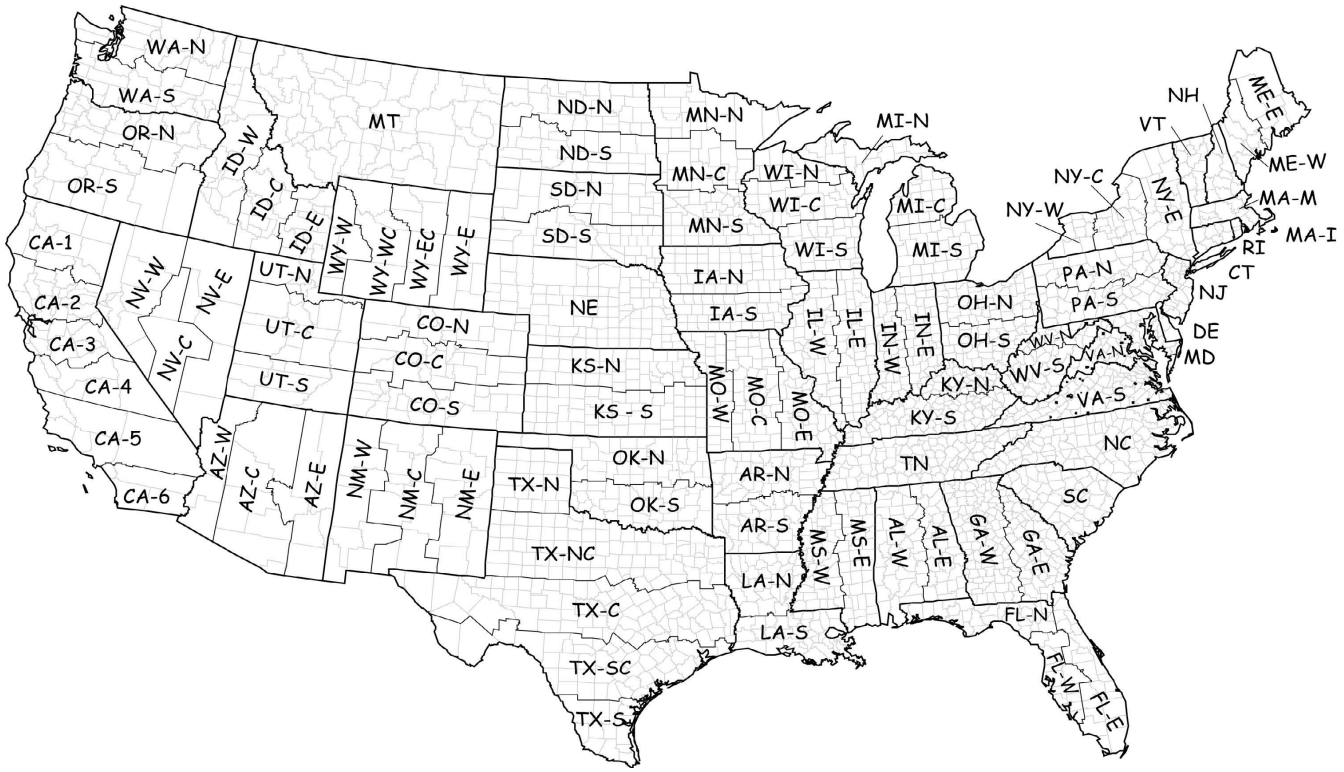


Map of Greenland with different projections

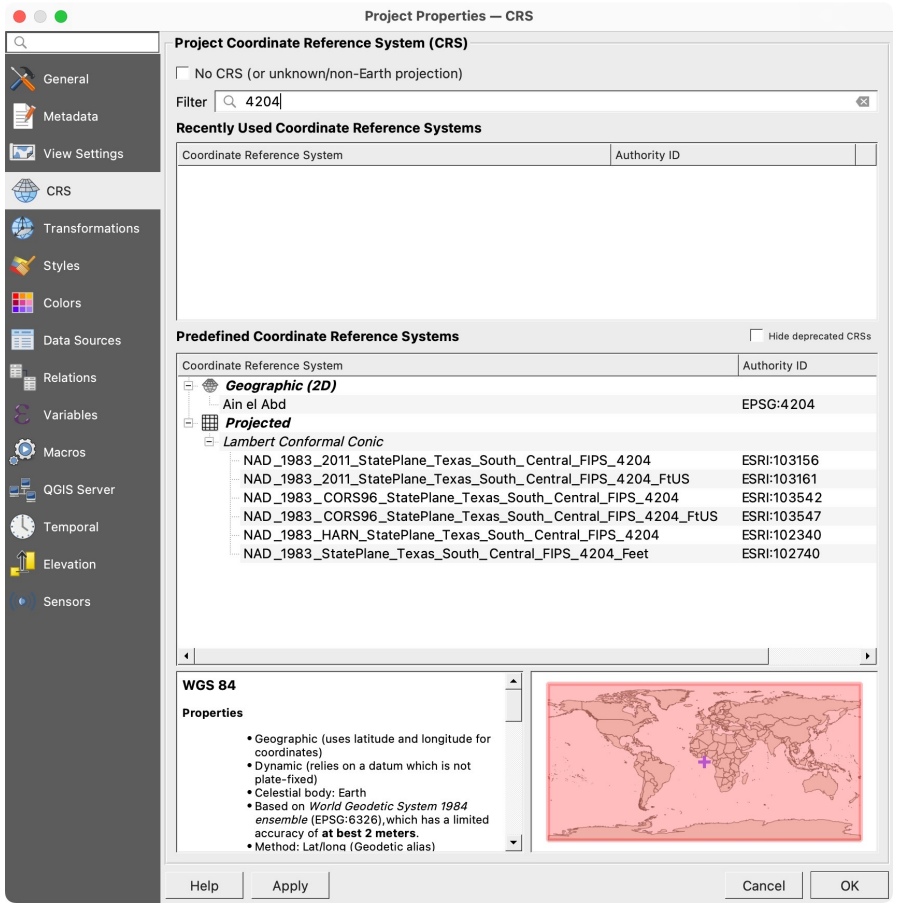
Greenland is good for CRS projections examples since it is an extreme case (far away from equator).

Property	Definition	Projection Type That Preserves It
Area	The relative size of regions is maintained.	Equal-area projections (e.g., Albers)
Direction	Bearings from the center are accurate.	Azimuthal projections (e.g., Lambert)
Distance	Correct distances are preserved along specific lines or from specific points.	Equidistant projections (e.g., Equirectangular)
Shape	Local angles and shapes are maintained, though areas are distorted.	Conformal projections (e.g., Mercator)

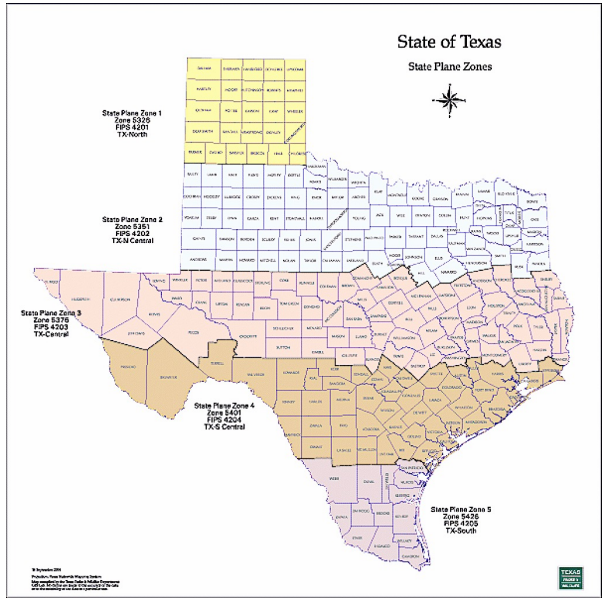
- The **State Plane Coordinate System** (SPCS) is a set of geographic zones or coordinate systems designed for specific regions of the United States. Each U.S. state contains one or more state plane zones, the boundaries of which usually follow county lines.

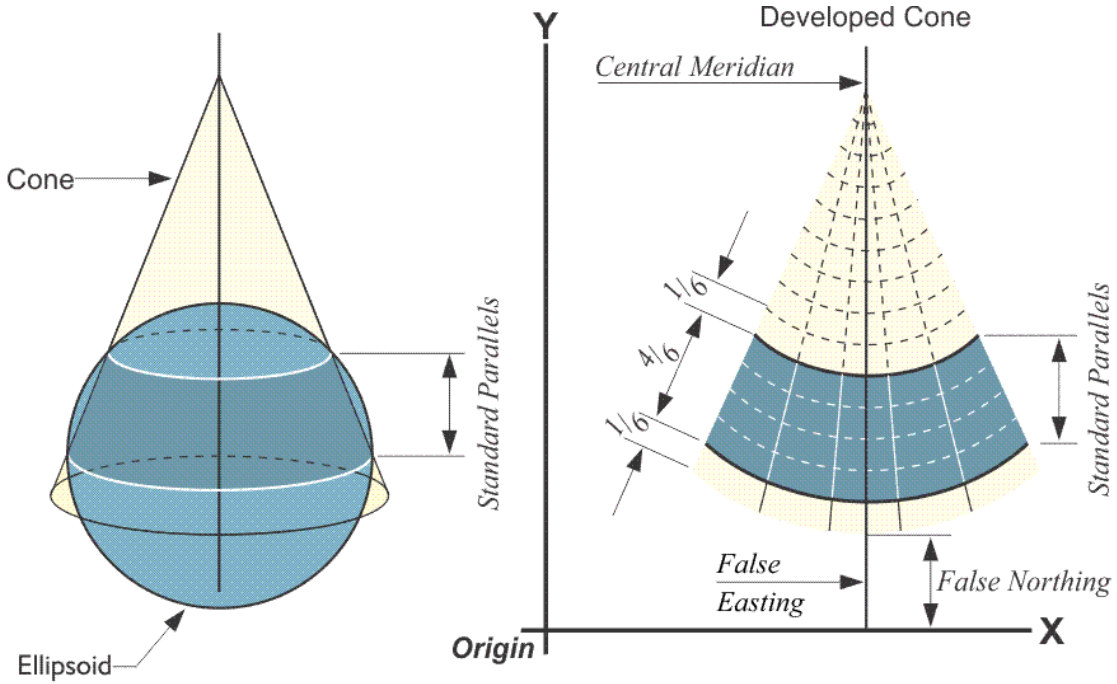


- The State Plane Coordinate System (SPCS) is widely used for geographic data by state and local governments.



- Texas is divided into **five** State Plane Coordinate System (SPCS) zones due to its large size.
- Each zone uses a **Lambert Conformal Conic** projection, which is ideal for east-west-oriented regions like Texas.
- Each zone is designed to minimize distortion and provide high accuracy for surveying, mapping, and engineering applications.
- The most common State Plane Coordinate Reference Systems (CRS) for Texas are:
  - NAD83 Texas North (FIPS 4201)
  - NAD83 Texas North Central (FIPS 4202)
  - NAD83 Texas Central (FIPS 4203)
  - NAD83 Texas South Central (FIPS 4204)
  - NAD83 Texas South (FIPS 4205)



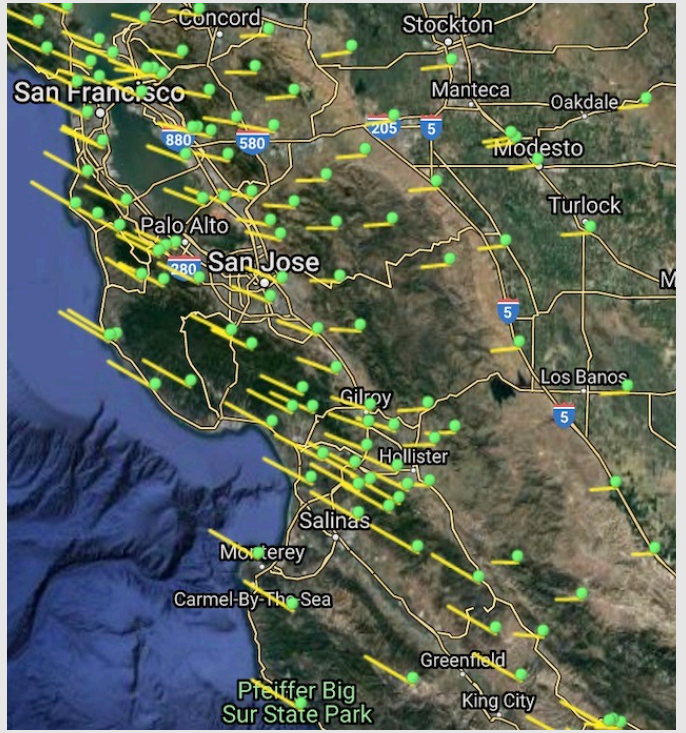


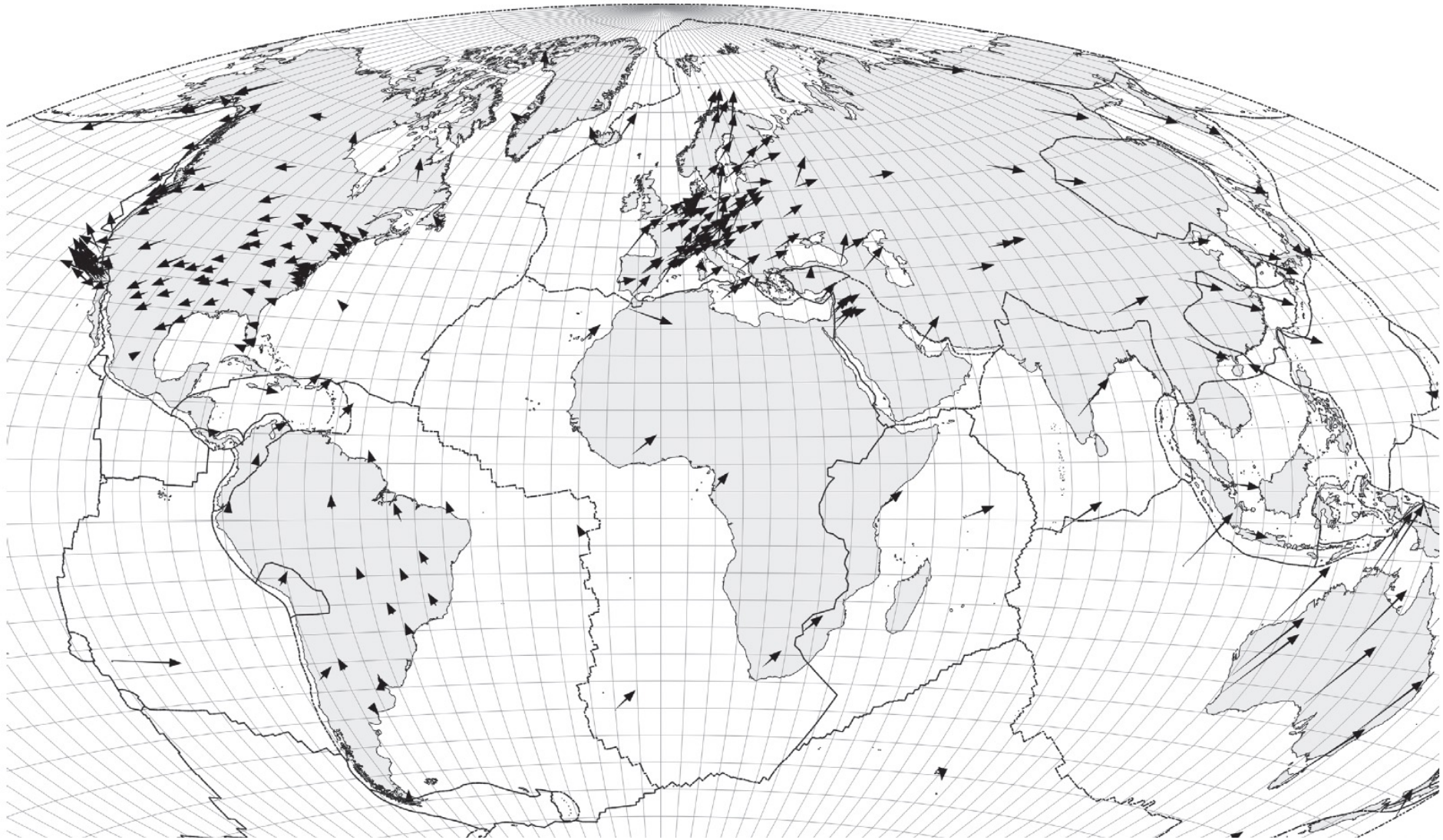
Lambert Conformal Conic Projection

Monuments

[NGS Web Map]

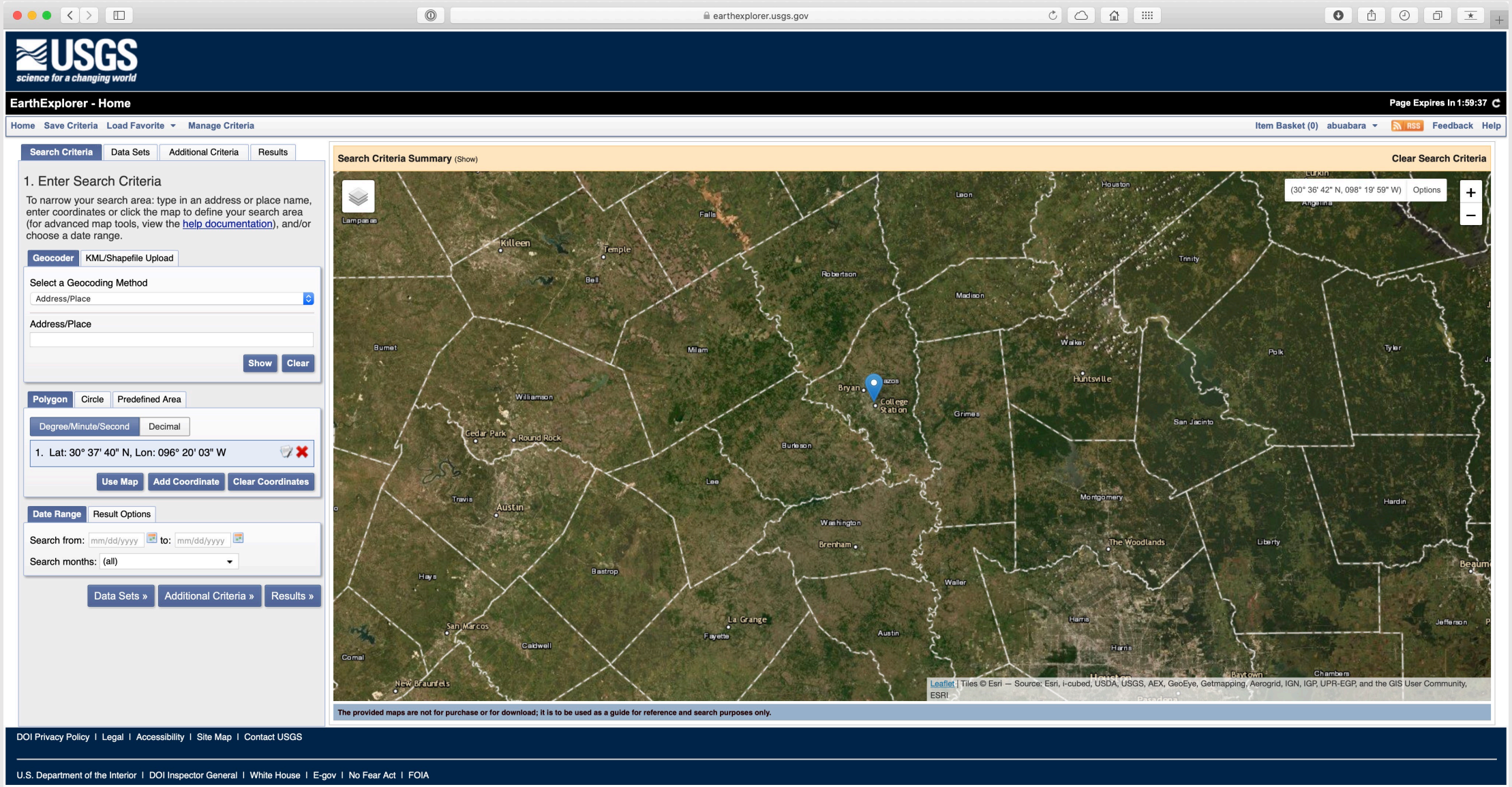
- **Survey monuments** (also called survey marks, survey markers, survey benchmarks, or geodetic marks) are objects placed to mark key survey points on the Earth's surface.
- A monument is a **physical marker** placed at a specific location. It helps map out coordinates (latitude and longitude) accurately.
- **Up to the 1980s**, surveyors placed benchmarks as precise starting points for local surveys, creating maps, or analyzing land.
- *But* **plates are always moving** and lat/long of any point changes with time. GPS/GNSS can provide higher accuracy.





Readings

1. **Choosing the right map projection**
   https://source.opennews.org/articles/choosing-right-map-projection/
2. **Map projections: A working manual**
   https://www.usgs.gov/publications/map-projections-a-working-manual
3. **Map projections**
   https://pubs.usgs.gov/gip/70047422/report.pdf


earthexplorer.usgs.gov
USGS
science for a changing world
EarthExplorer - Home
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Home Save Criteria Load Favorite Manage Criteria
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Search Criteria Data Sets Additional Criteria Results
1. Enter Search Criteria
To narrow your search area: type in an address or place name, enter coordinates or click the map to define your search area (for advanced map tools, view the help documentation), and/or choose a date range.
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Bryan
College Station
Grimes
San Jacinto
Cedar Park
Round Rock
Burleson
Lee
Travis
Austin
Montgomery
Hardin
Washington
Brenham
The Woodlands
Liberty
Bastrop
Waller
Hays
San Marcos
La Grange
Fayette
Caldwell
Harris
Jefferson
Comal
New Braunfels
Chambers
Baytown
Leaflet | Tiles © Esri — Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community, ESRI
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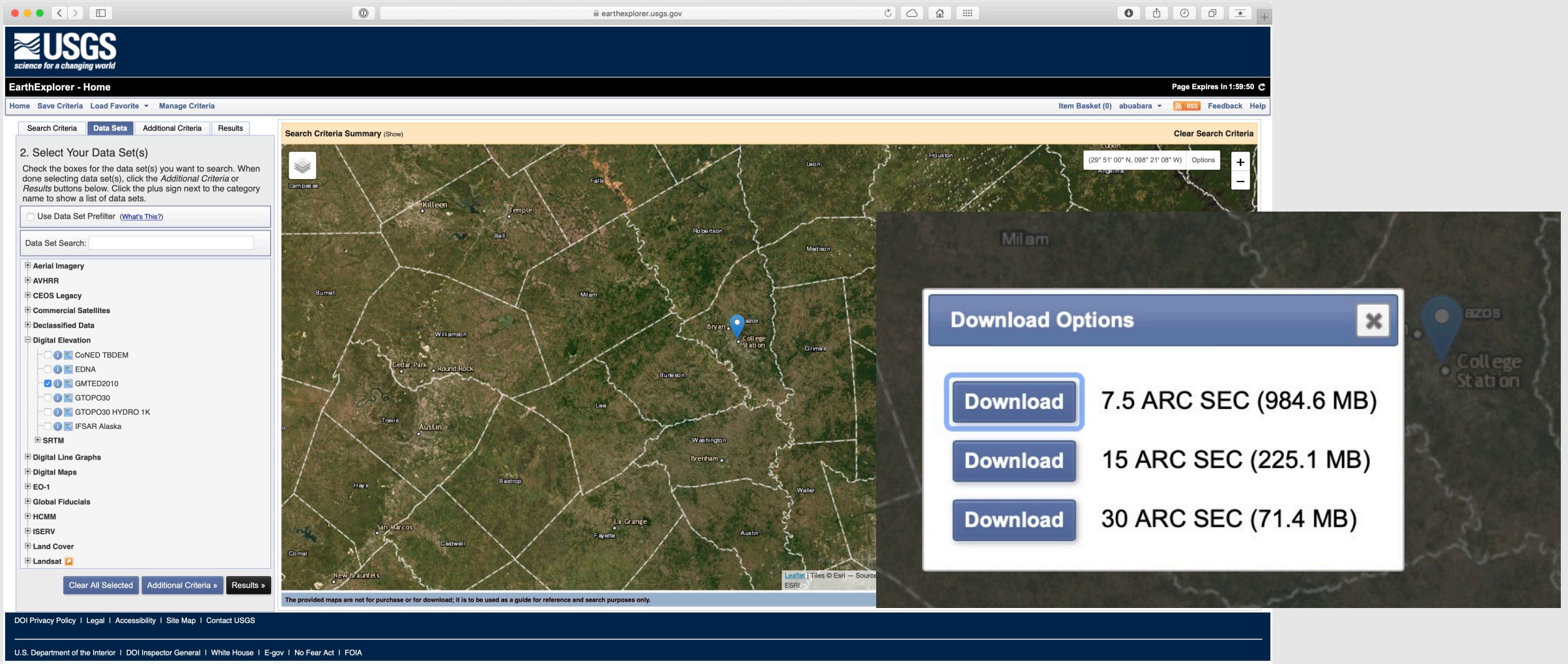
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Home Save Criteria Load Favorite Manage Criteria
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Search Criteria Data Sets Additional Criteria Results
2. Select Your Data Set(s)
Check the boxes for the data set(s) you want to search. When done selecting data set(s), click the Additional Criteria or Results buttons below. Click the plus sign next to the category name to show a list of data sets.
Use Data Set Prefilter (What's This?)
Data Set Search:
Aerial Imagery
AVHRR
CEOS Legacy
Commercial Satellites
Declassified Data
Digital Elevation
CoNED TBDEM
EDNA
GMTED2010
GTOPO30
GTOPO30 HYDRO 1K
IFSAR Alaska
SRTM
Digital Line Graphs
Digital Maps
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ISERV
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Round Rock
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Travis
Austin
Lee
Washington
Brenham
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Waller
San Marcos
La Grange
Fayette
Caldwell
Comal
New Braunfels
Leaflet | Tiles © Esri — Source: ESRI
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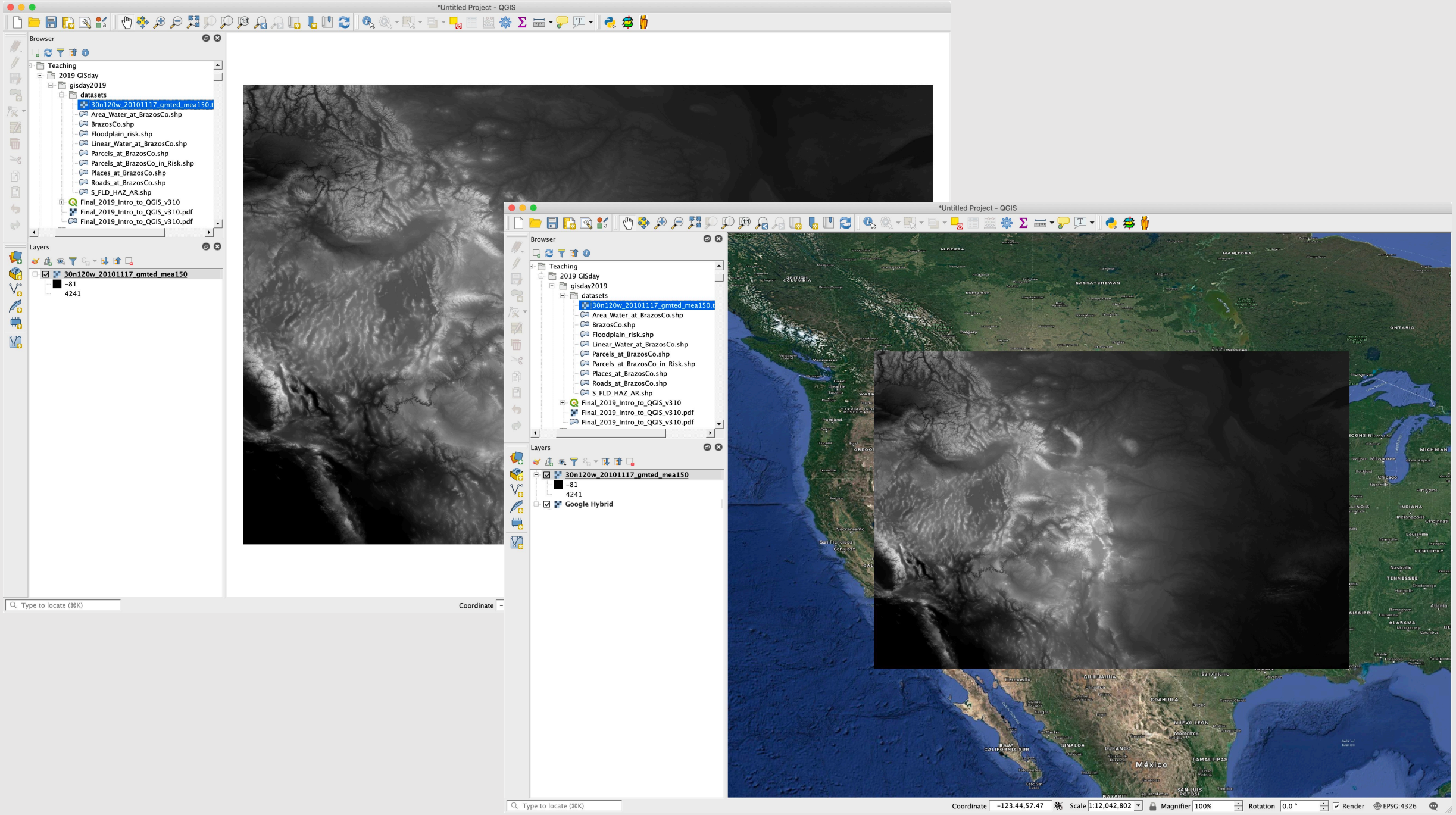
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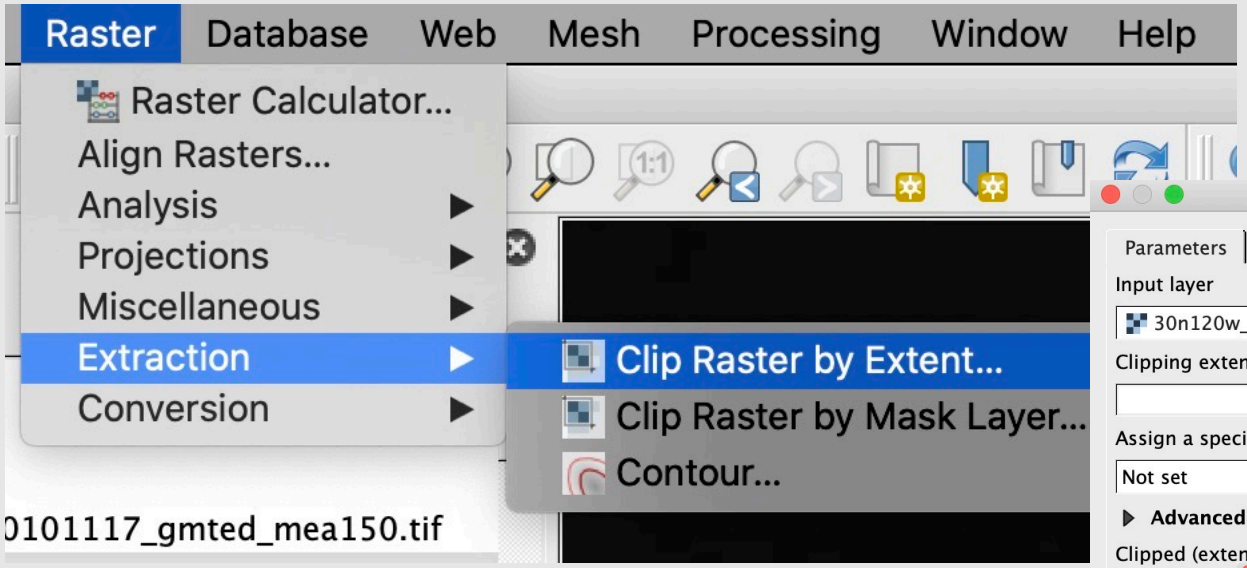
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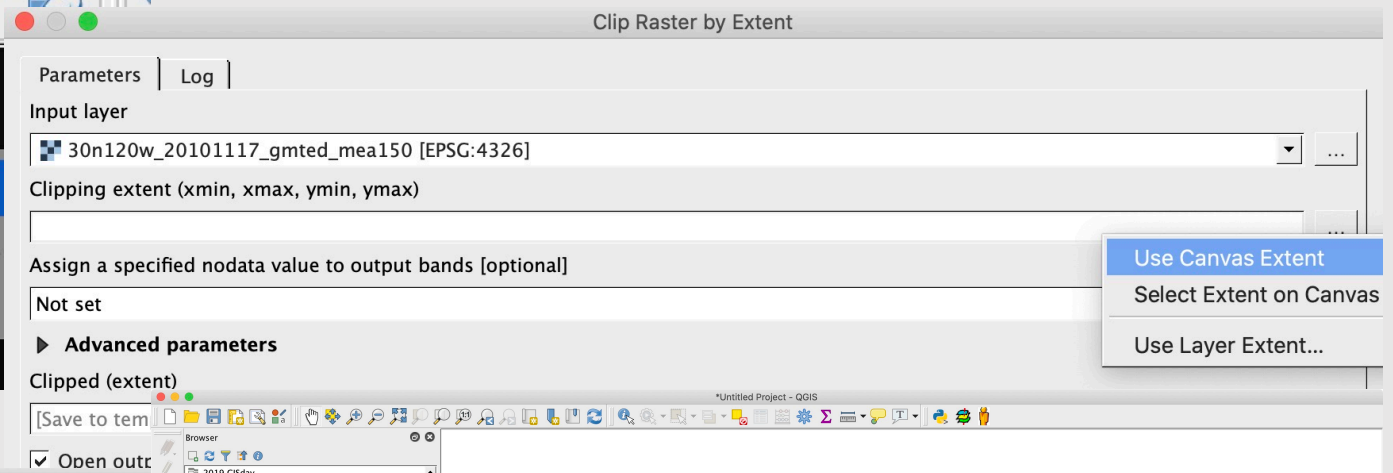
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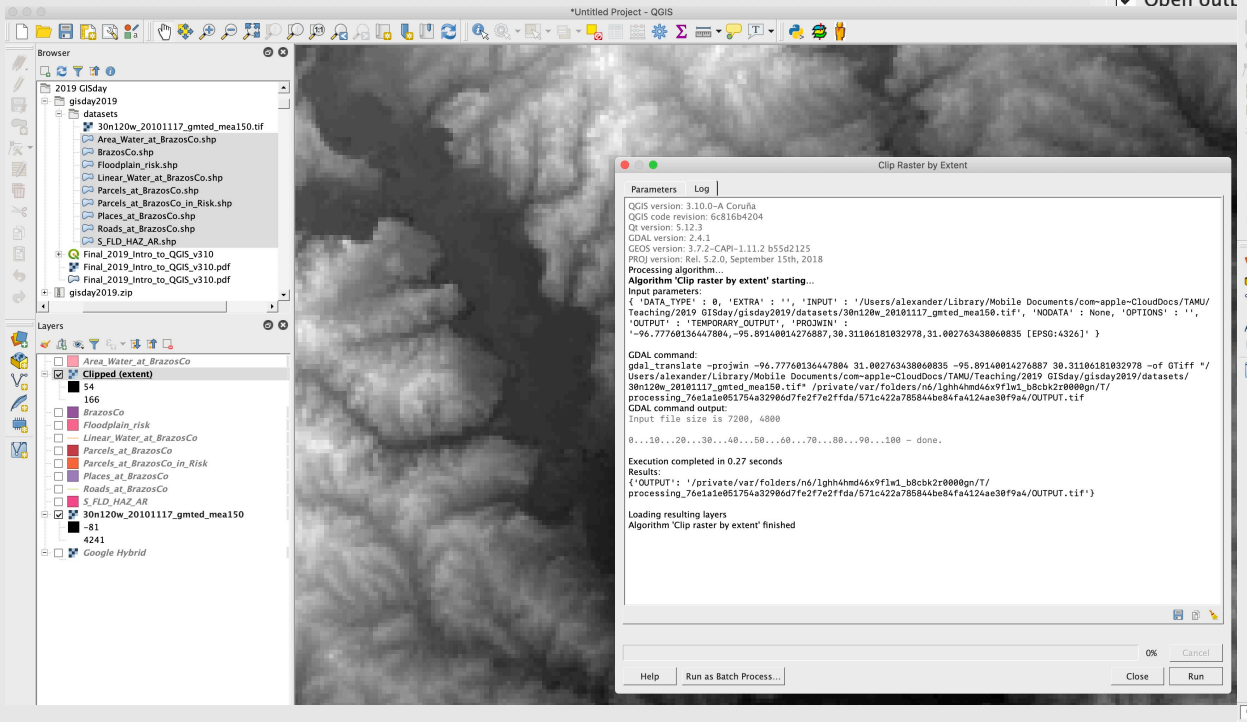
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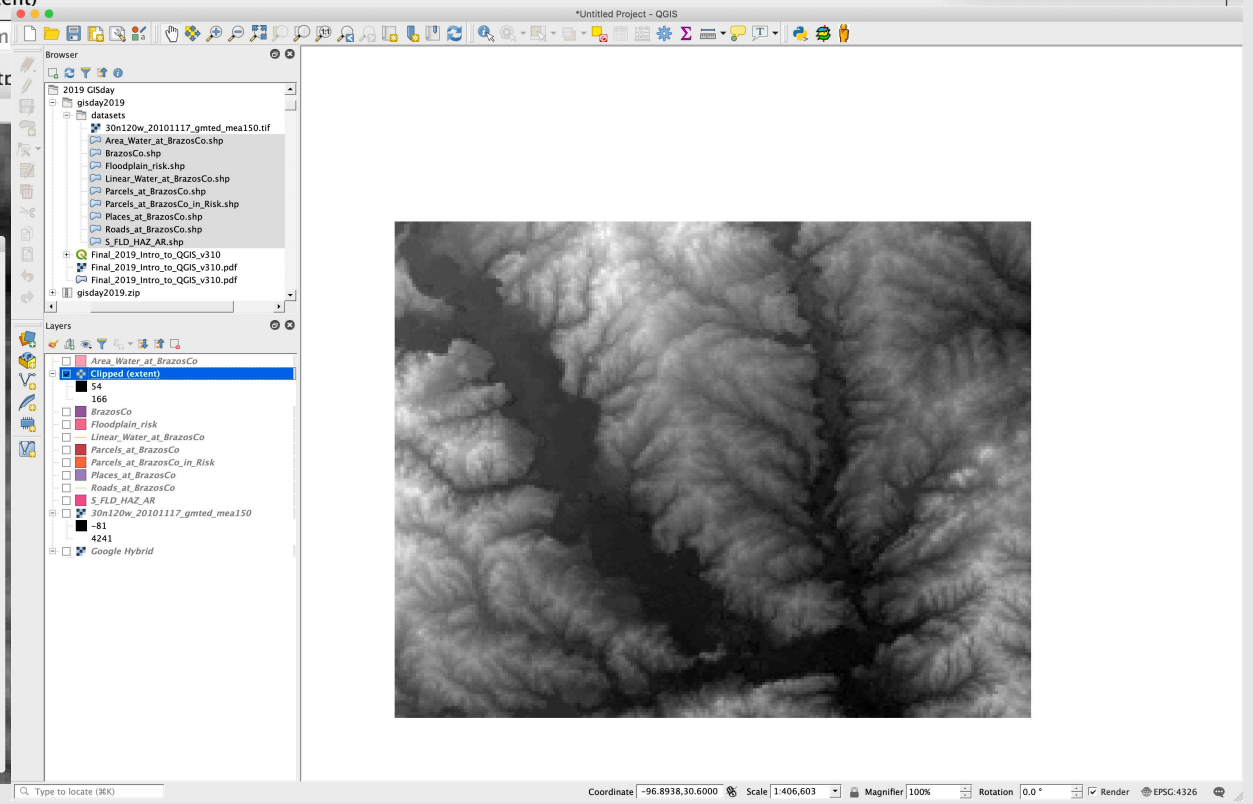
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Analysis
Projections
Miscellaneous
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Conversion

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Layers

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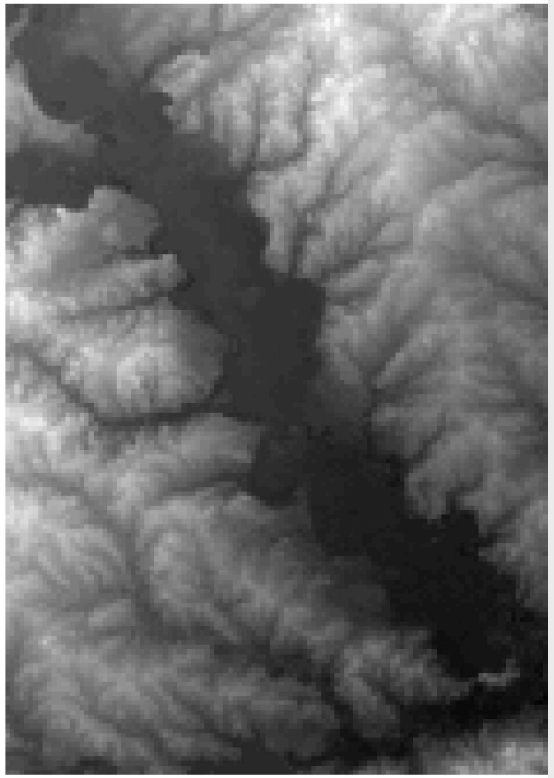

Contour

Parameters | Log

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Band 1 (Gray)

Interval between contour lines
1

Attribute name (if not set, no elevation attribute is attached) [optional]
ELEV

Offset from zero relative to which to interpret intervals [optional]
0.000000

Advanced parameters

Contours
[Save to temporary file]

Open output file after running algorithm

GDAL/OGR console call

```
gdal_contour -b 1 -a ELEV -i 1.0 -f "GPKG" /private/var/folders/n6/lghh4hmd46x9flw1_b8cbk2r0000gn/T/
processing_76e1a1e051754a32906d7fe2f7e2ffda/571c422a785844be84fa4124ae30f9a4/OUTPUT.tif /private/var/folders/n6/
lghh4hmd46x9flw1_b8cbk2r0000gn/T/processing_76e1a1e051754a32906d7fe2f7e2ffda/c9d821561f4f4624954c70d95e9b53e7/
OUTPUT.gpkg
```

0%
Cancel

Help
Run as Batch Process...
Close
Run

Layer Properties - Contours | Symbology

Information
Source
Symbology
Labels
Diagrams
3D View
Fields
Attributes Form
Joins
Auxiliary Storage
Actions
Display
Rendering
Variables
Metadata
Dependencies
Legend
QGIS Server
Digitizing

Categorized

Value 1.2 ELEV

Symbol

Color ramp

Symbol	Value	Legend
	all othe...	
	55	55
	56	56
	57	57
	58	58
	59	59
	60	60
	61	61
	62	62
	63	63
	64	64
	65	65
	66	66
	67	67
	68	68
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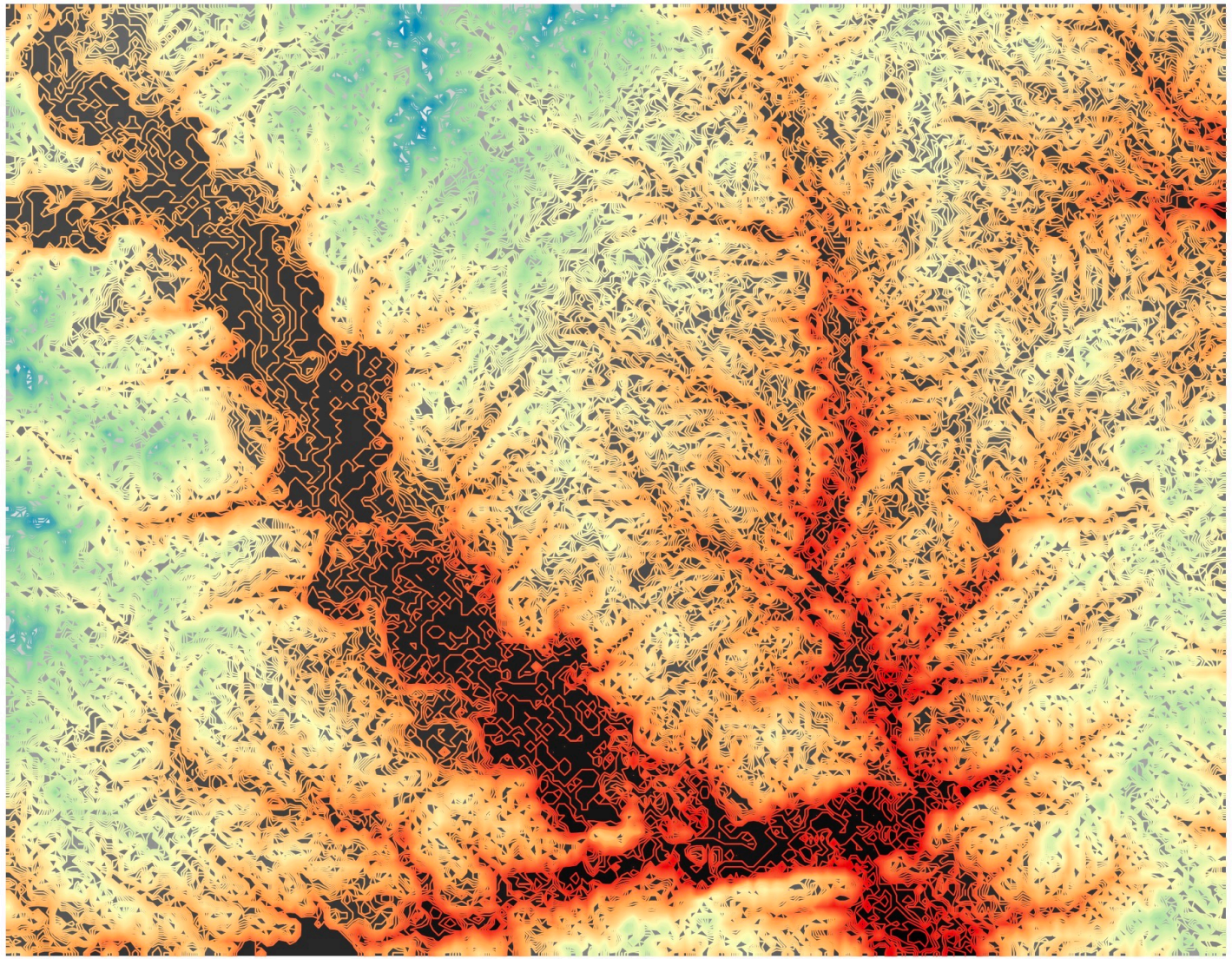
	79	79
	80	80
	81	81
	82	82
	83	83
	84	84
	85	85
	86	86
	87	87
	88	88
	89	89
	90	90
	91	91
	92	92

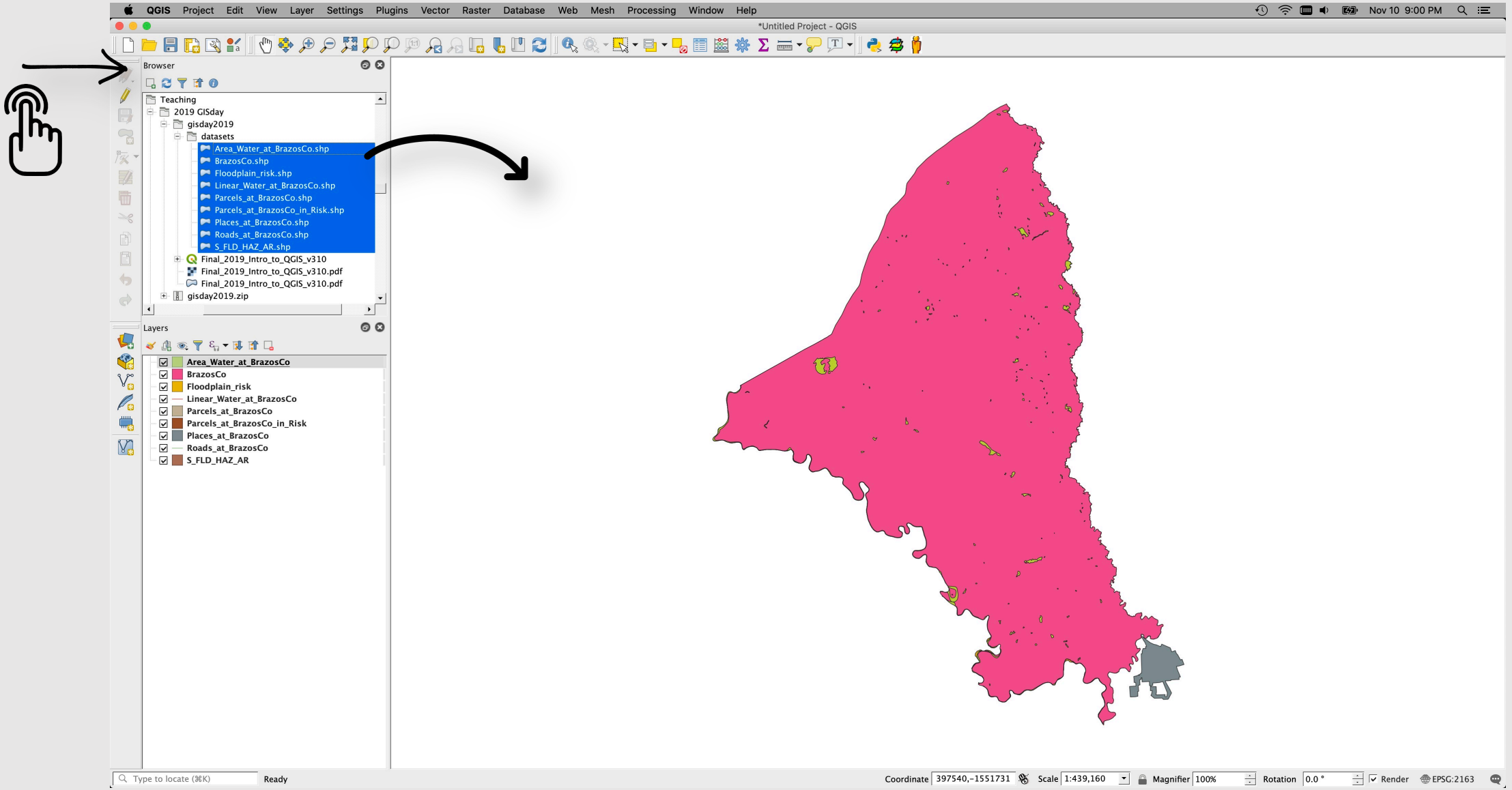
Classify | Delete All | Adv

Layer Rendering

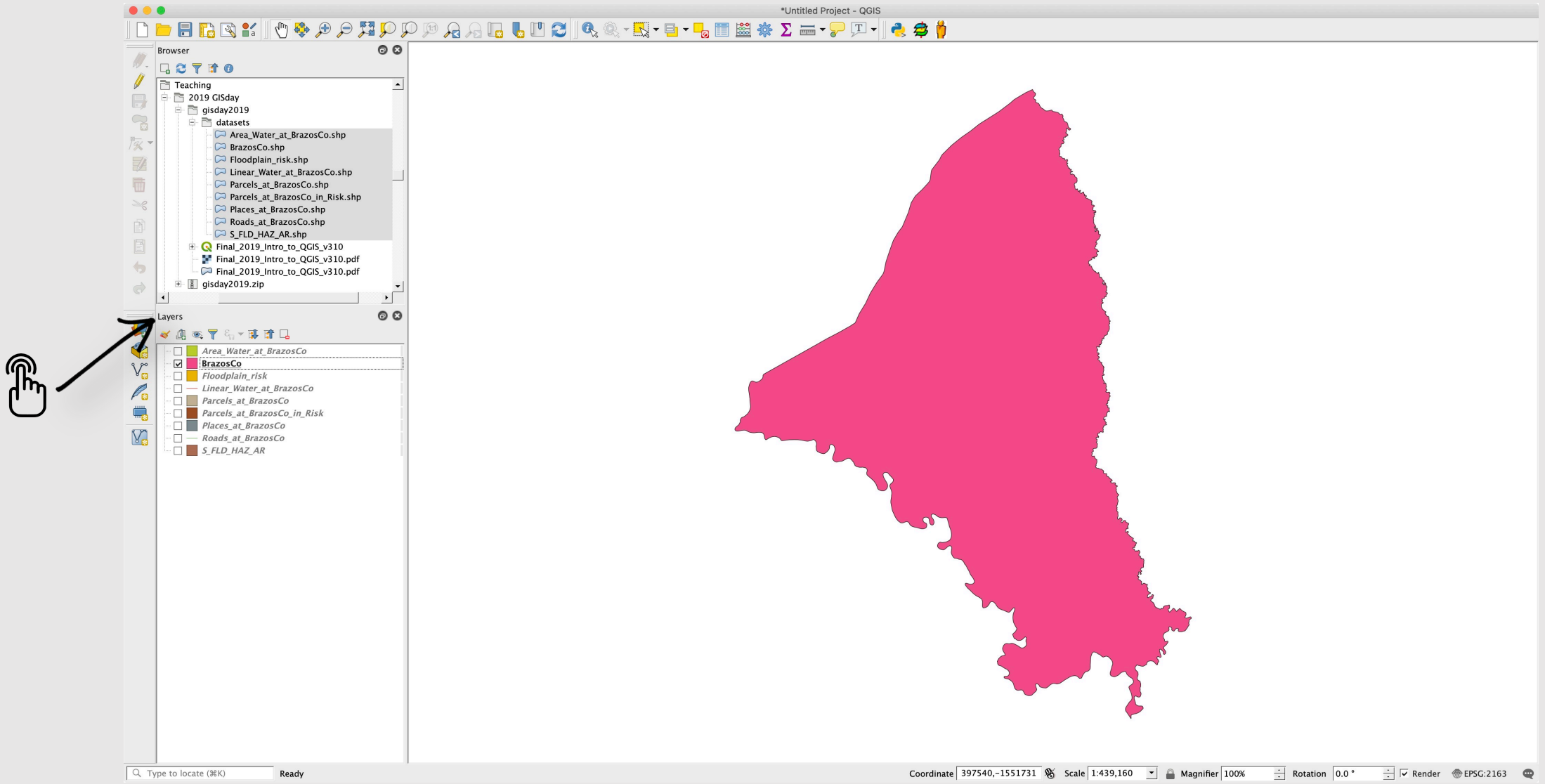
Help | Style | Apply | Cancel



Importing data (colors will vary!)

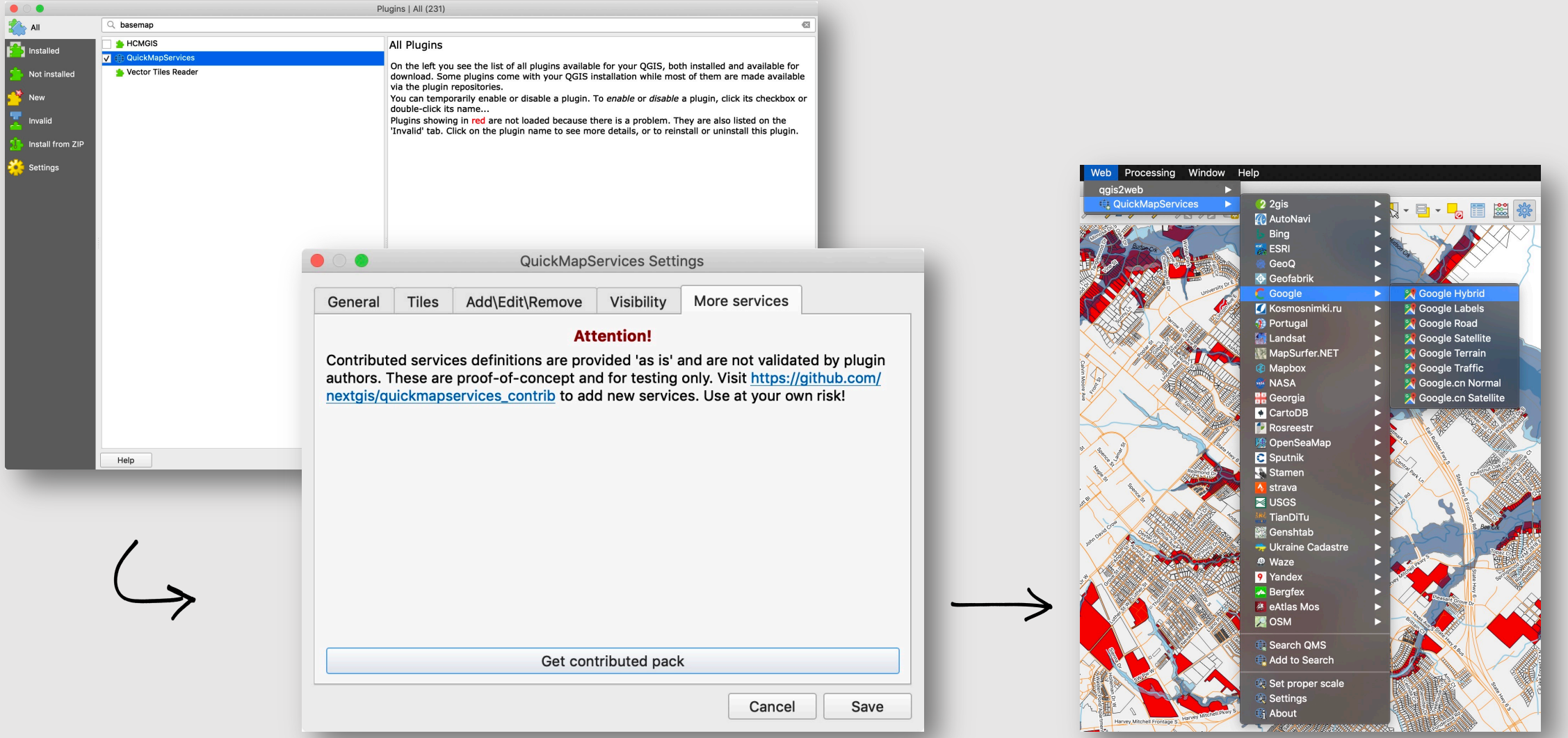


Importing data (colors will vary!)



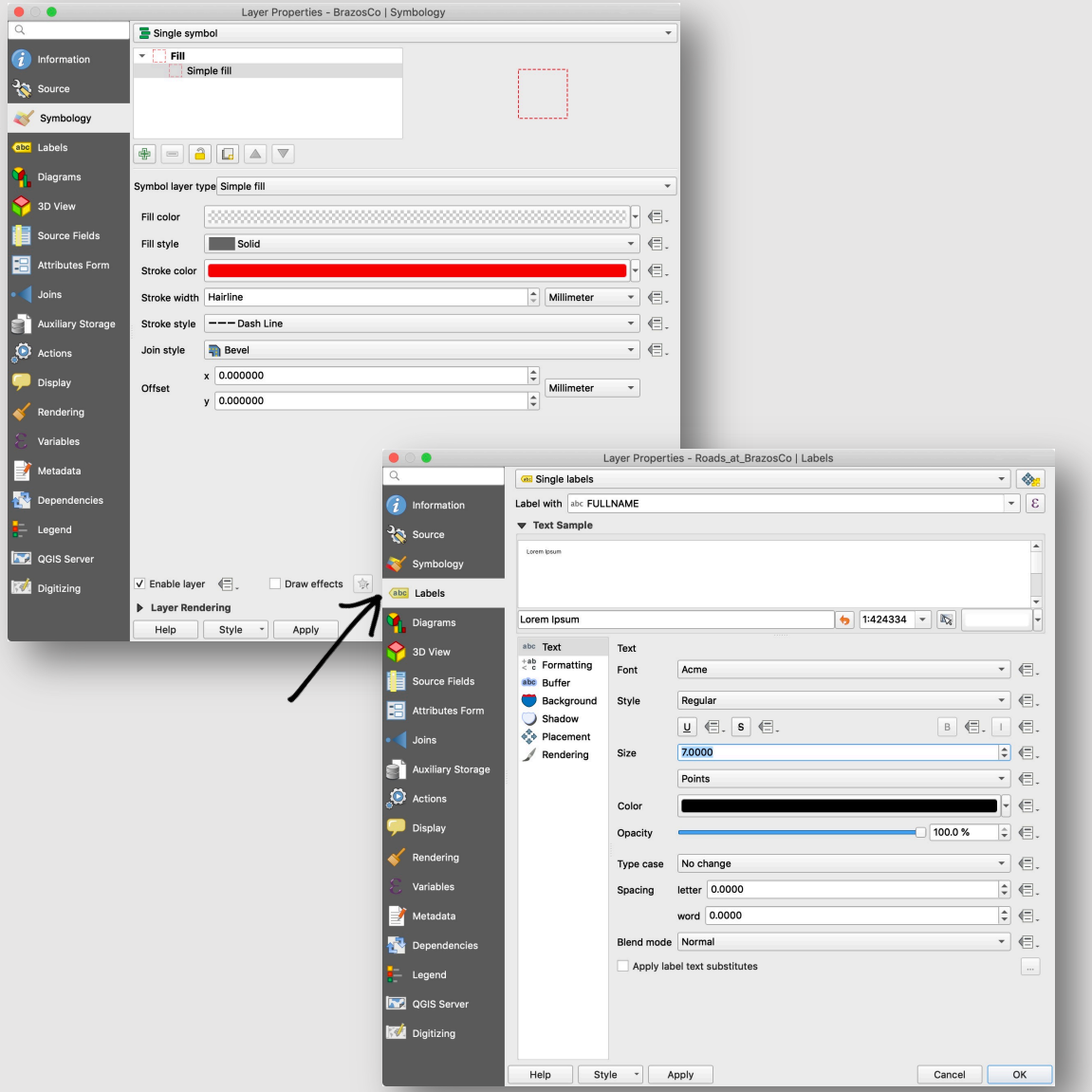
Extra hint

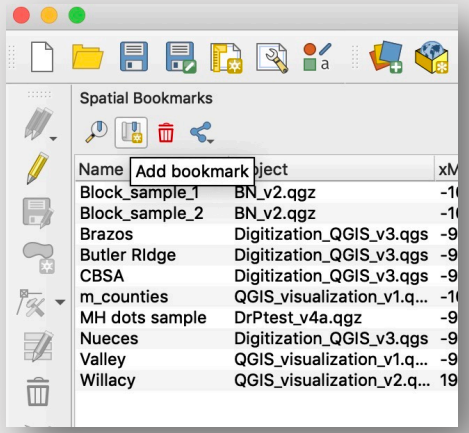
- Install plugins! search *basemaps* to include one basemap in your project



Let's practice …

- Turn layers off
- Configure layers and labels
  - Style: simple fill, categorize, lines
  - Labels: change font, size, buffer, position
- Reorder and rename layers
- Try different zooms
  - Zoom to layer
  - Back
  - **Bookmark**

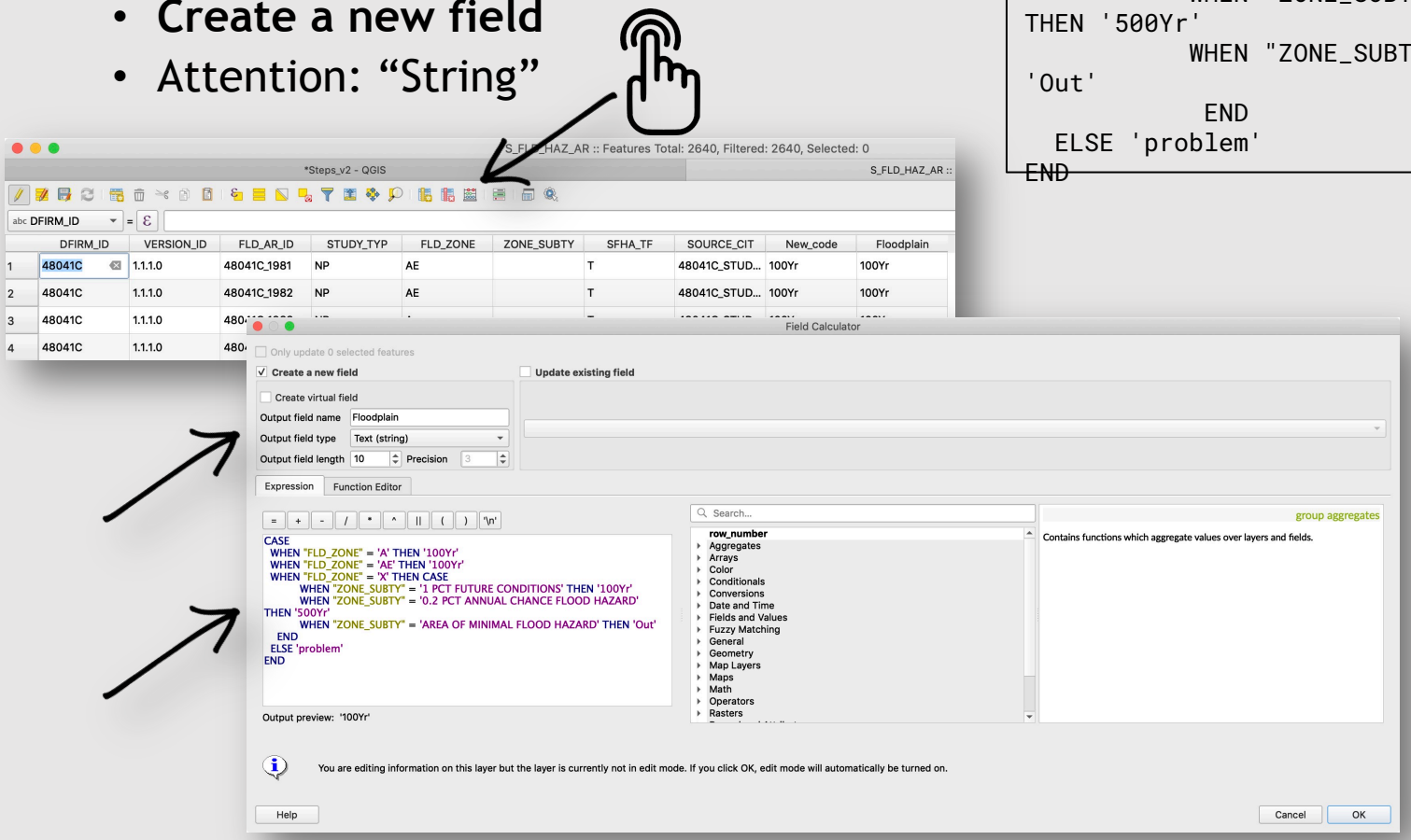




Create a new field, and calculate it

- Let’s work just with the **flood layer** now
- Explore the attribute table
- Open field calculator
  - **Create a new field**
  - Attention: “String”

```
CASE
  WHEN "FLD_ZONE" = 'A' THEN '100Yr'
  WHEN "FLD_ZONE" = 'AE' THEN '100Yr'
  WHEN "FLD_ZONE" = 'X' THEN CASE
            WHEN "ZONE_SUBTY" = '1 PCT FUTURE CONDITIONS' THEN '100Yr'
            WHEN "ZONE_SUBTY" = '0.2 PCT ANNUAL CHANCE FLOOD HAZARD'
THEN '500Yr'
            WHEN "ZONE_SUBTY" = 'AREA OF MINIMAL FLOOD HAZARD' THEN
'Out'
             END
  ELSE 'problem'
END
```

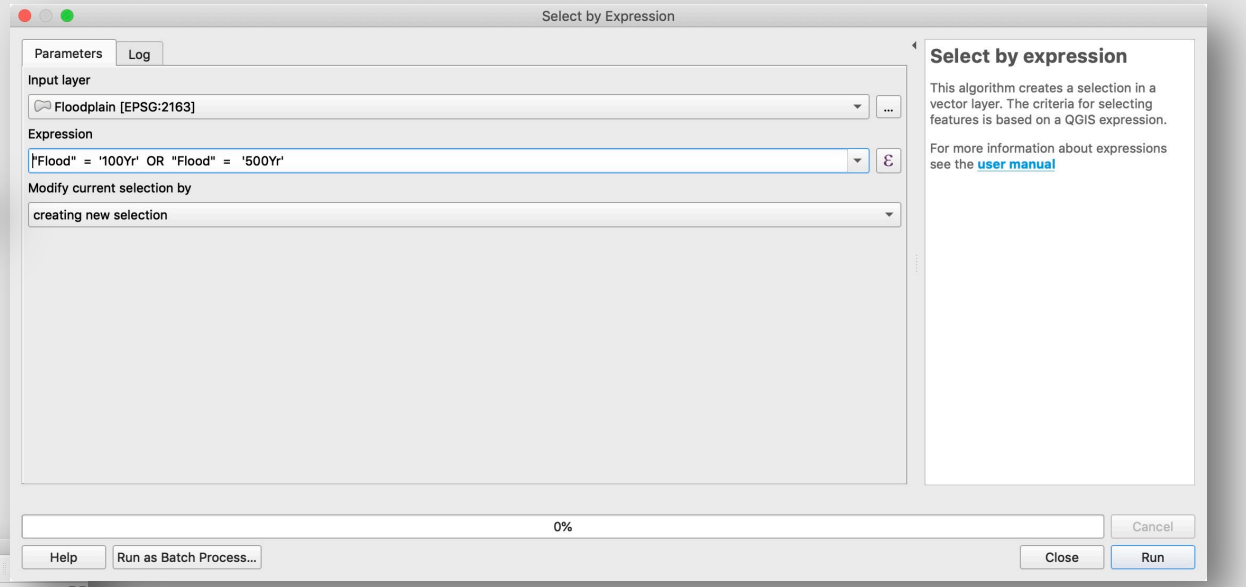


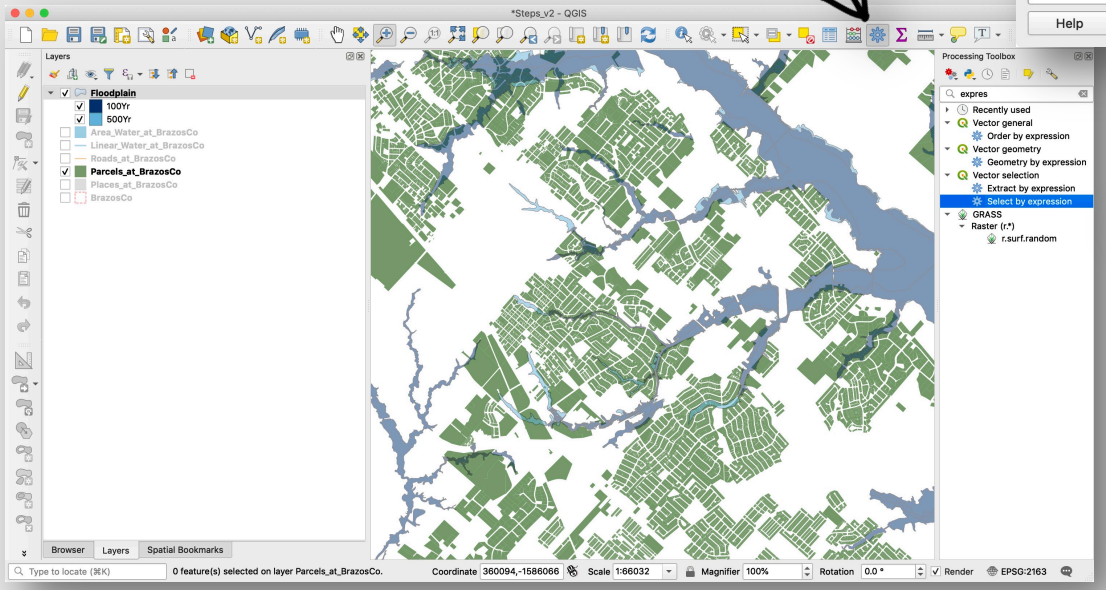
Select tool

- Explore the select tool:
  - **Select by expression**

3

1





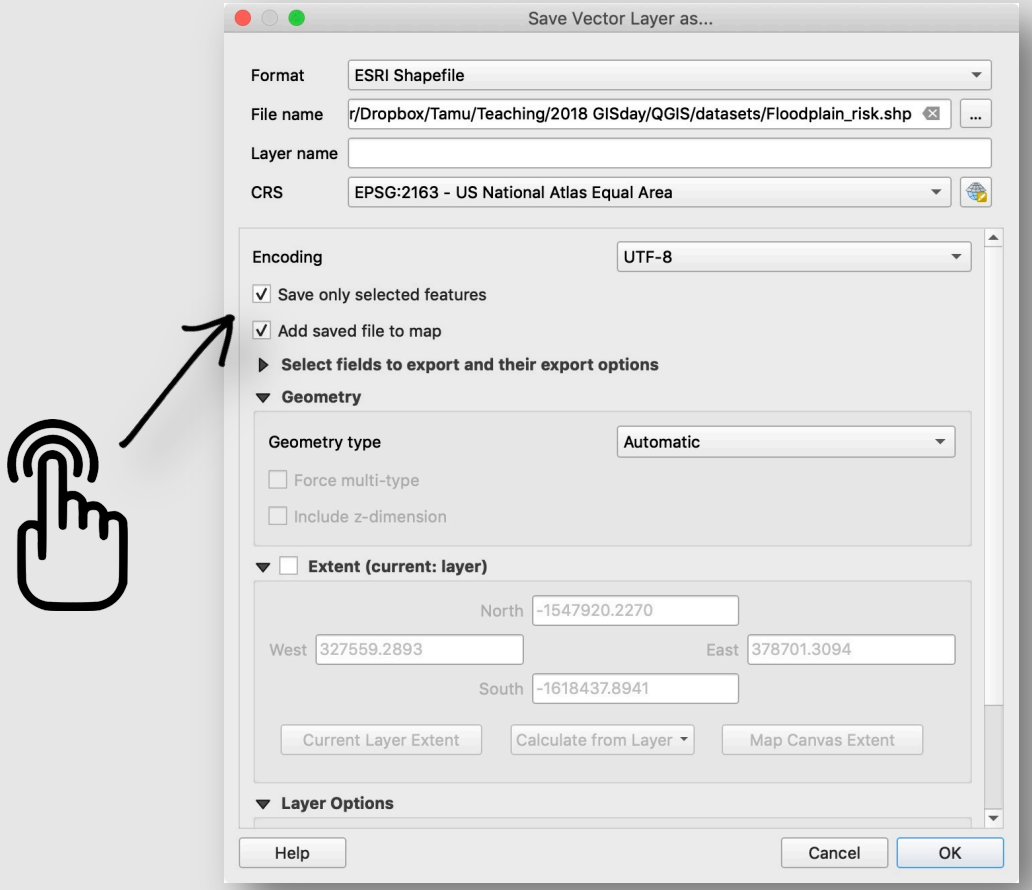
2

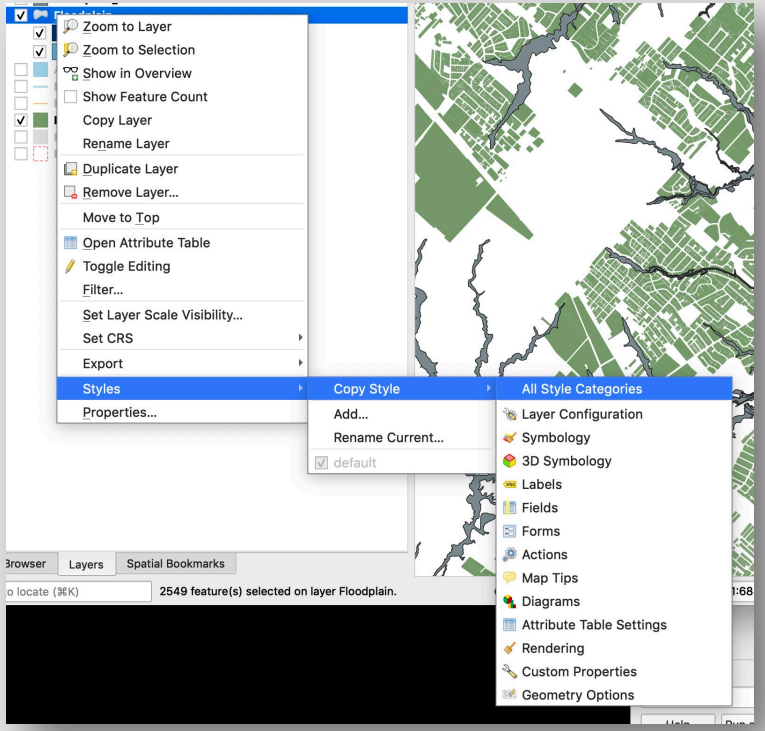
Ctrl + C

Ctrl + V

```
"Floodplain" = '100Yr' OR
"Floodplain" = '500Yr'
```

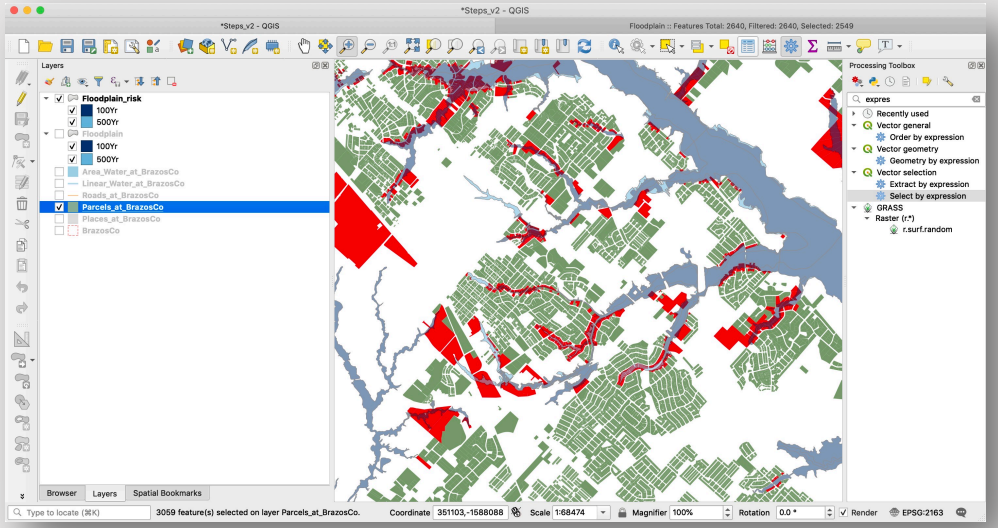
Export tool
and Copy and Paste styles

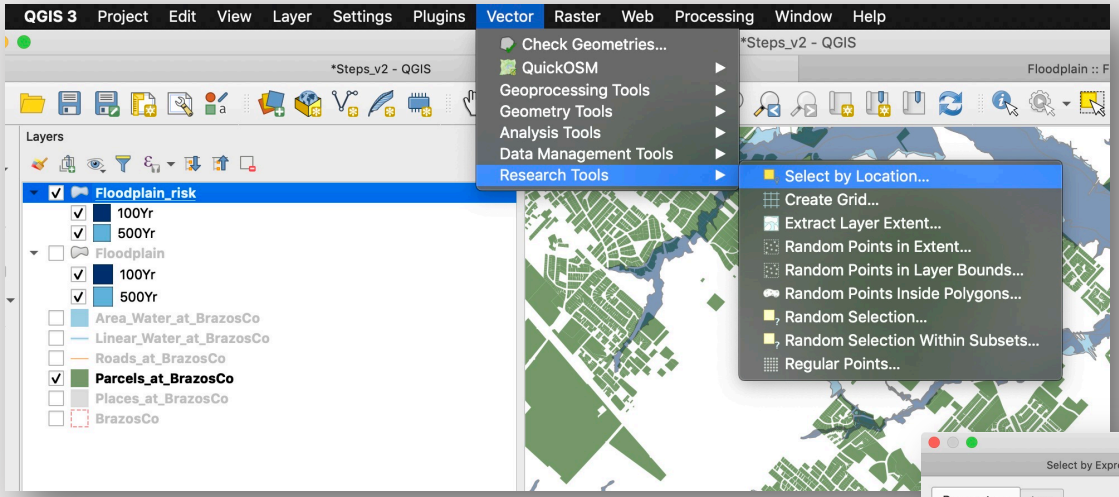


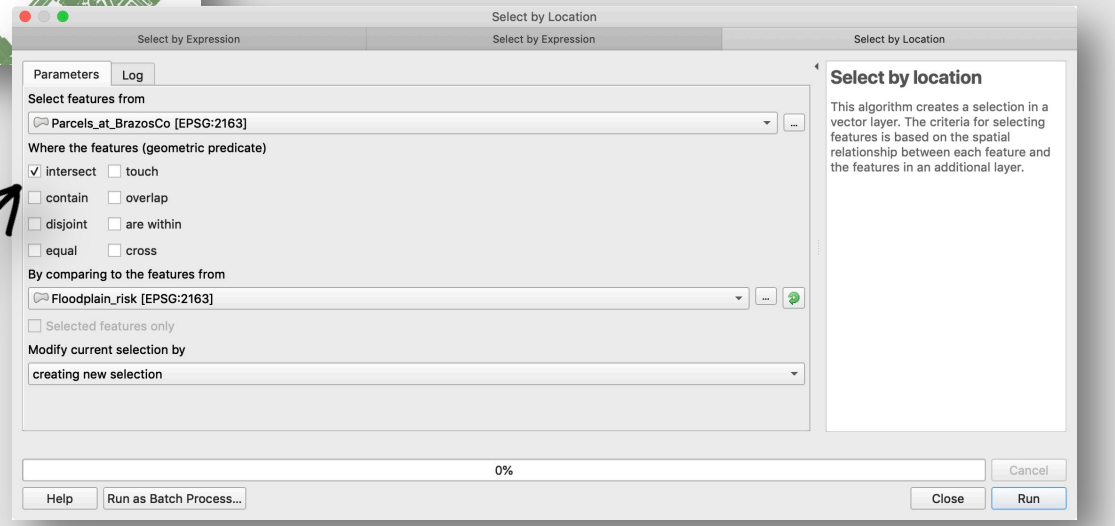


Select by location

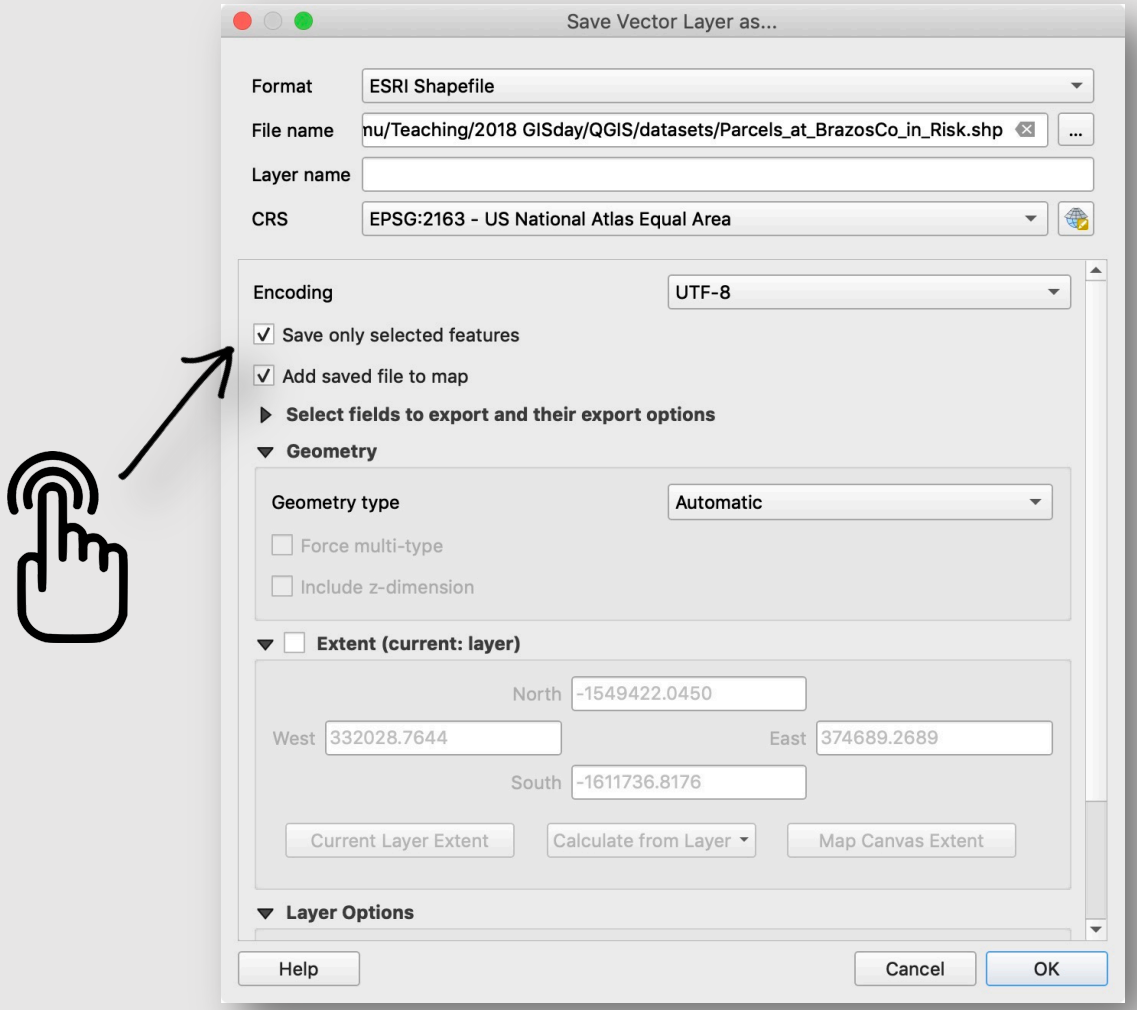
- Processing → Toolbox → Select by location
- Save only selected features (parcels A and B in risk)



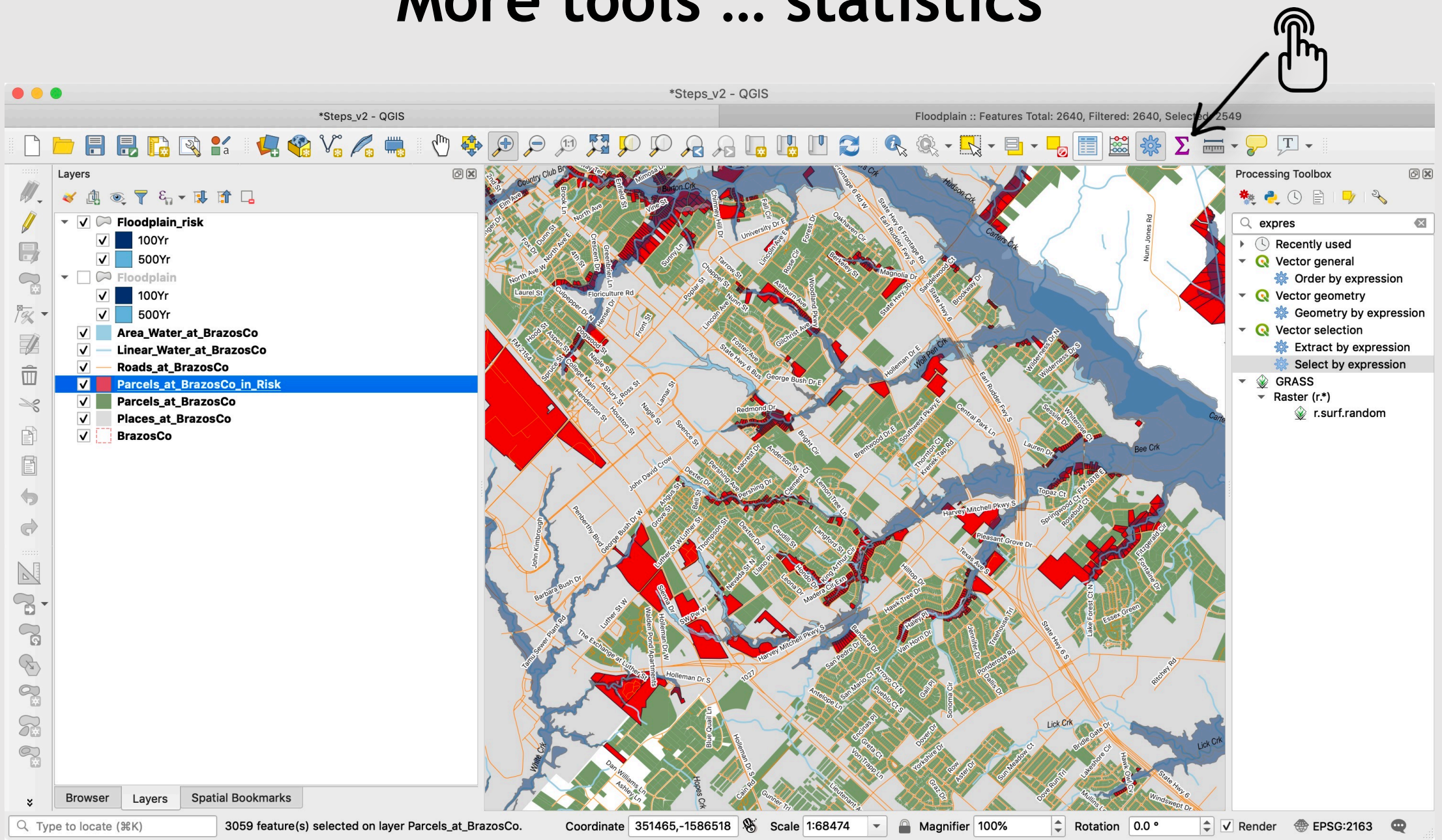




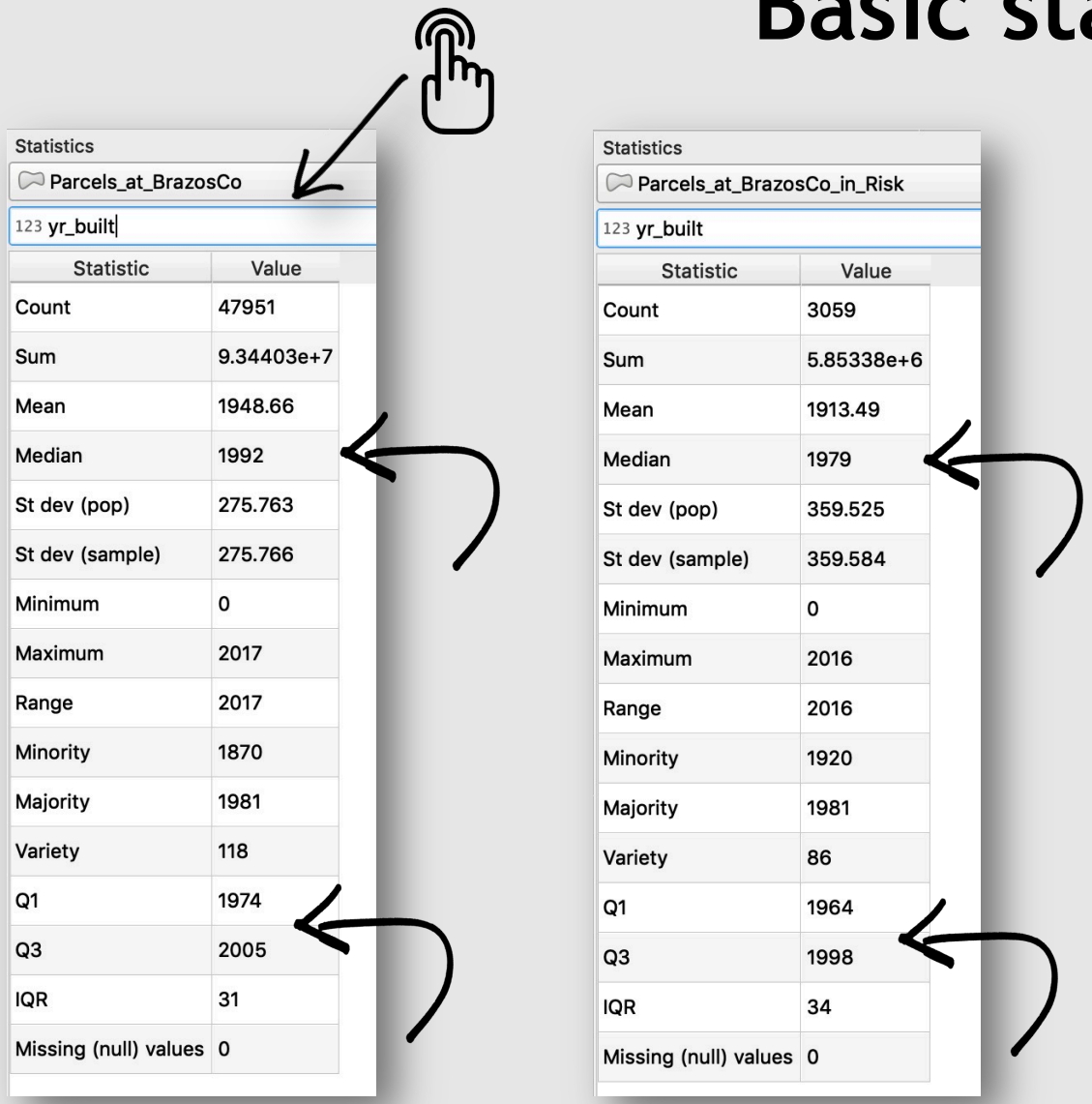
Export tool


Save Vector Layer as...
Format
ESRI Shapefile
File name
nu/Teaching/2018 GISday/QGIS/datasets/Parcels_at_BrazosCo_in_Risk.shp
...
Layer name
CRS
EPSG:2163 - US National Atlas Equal Area
Encoding
UTF-8
Save only selected features
Add saved file to map
Select fields to export and their export options
Geometry
Geometry type
Automatic
Force multi-type
Include z-dimension
Extent (current: layer)
North
-1549422.0450
West
332028.7644
East
374689.2689
South
-1611736.8176
Current Layer Extent
Calculate from Layer
Map Canvas Extent
Layer Options
Help
Cancel
OK

More tools … statistics



Basic statistics



Statistics

Parcels_at_BrazosCo

123 yr_built

Statistic	Value
Count	47951
Sum	9.34403e+7
Mean	1948.66
Median	1992
St dev (pop)	275.763
St dev (sample)	275.766
Minimum	0
Maximum	2017
Range	2017
Minority	1870
Majority	1981
Variety	118
Q1	1974
Q3	2005
IQR	31
Missing (null) values	0

Statistics

Parcels_at_BrazosCo_in_Risk

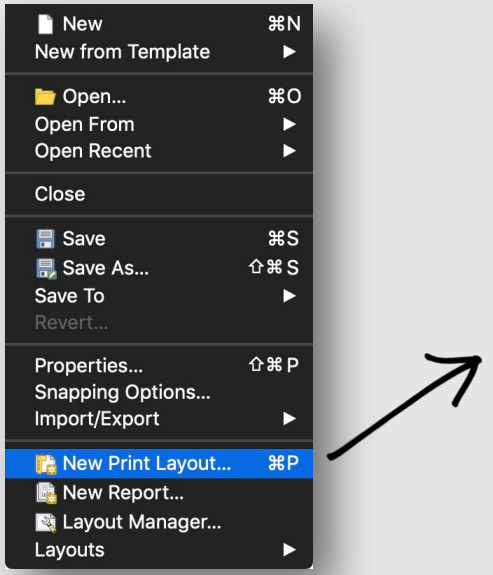
123 yr_built

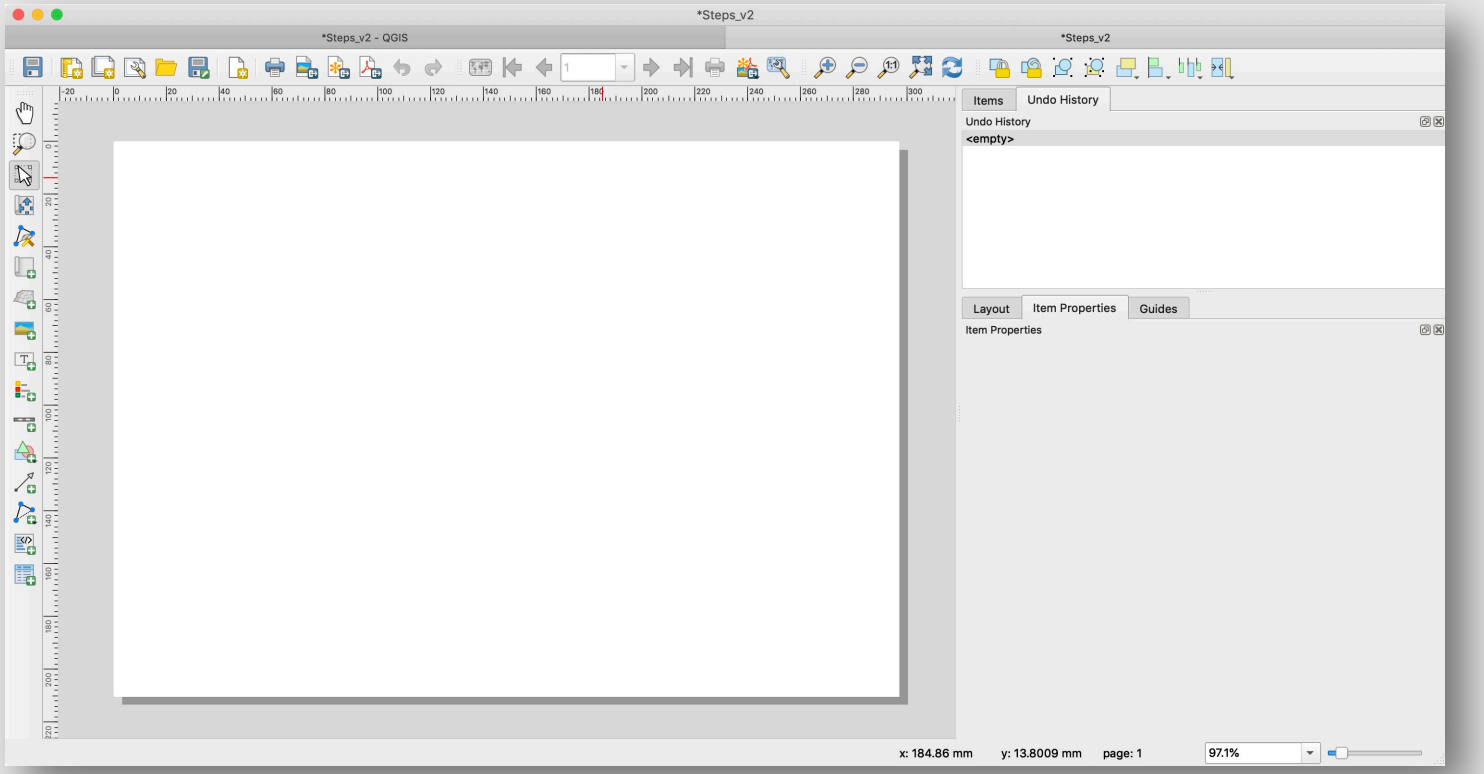
Statistic	Value
Count	3059
Sum	5.85338e+6
Mean	1913.49
Median	1979
St dev (pop)	359.525
St dev (sample)	359.584
Minimum	0
Maximum	2016
Range	2016
Minority	1920
Majority	1981
Variety	86
Q1	1964
Q3	1998
IQR	34
Missing (null) values	0

- 3059 out of 47951 houses in risk (6.4%)
- Some evidence that older houses are in greater risk of flood inundation

Print it!

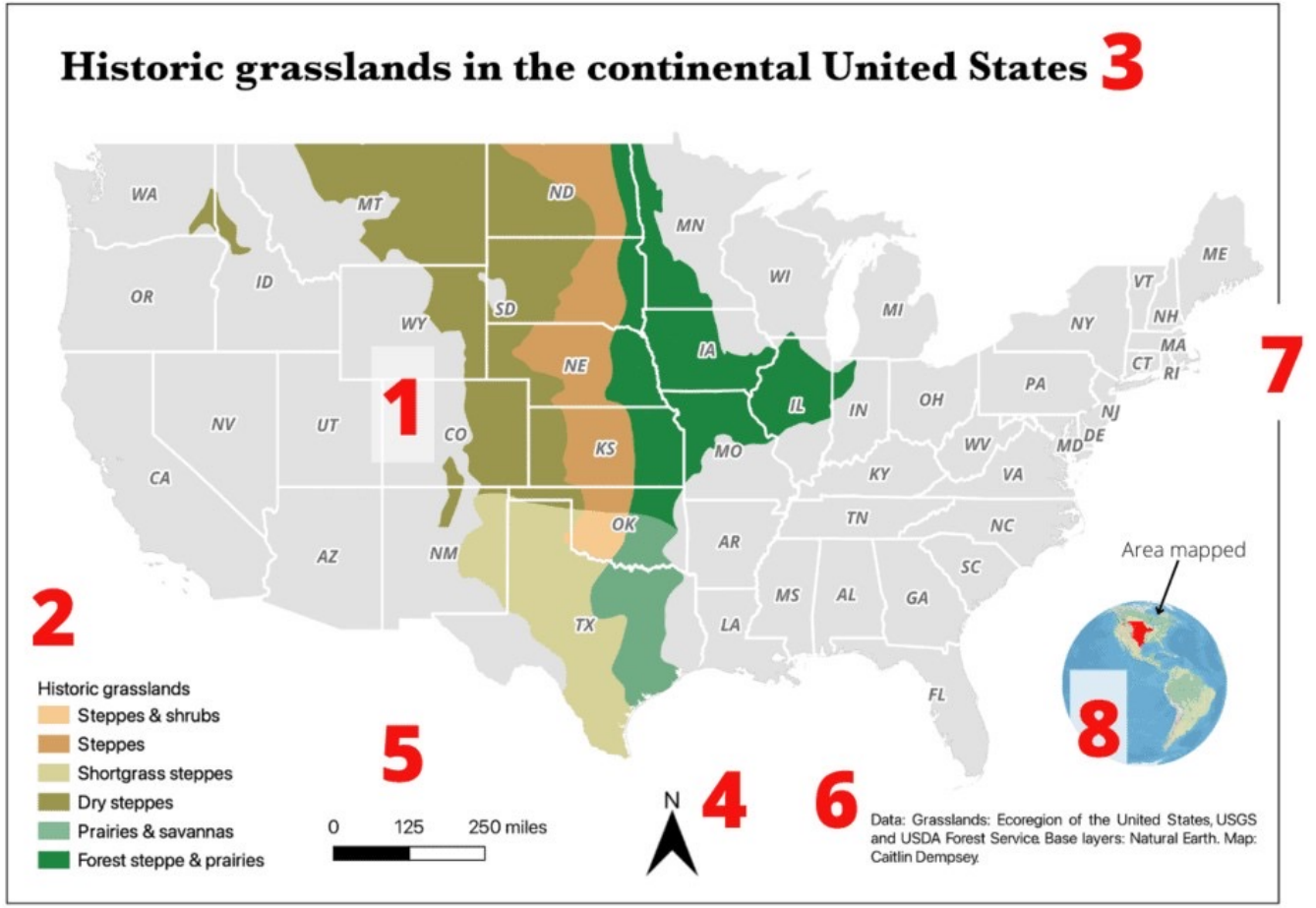
1. Project → New Print Layout
2. New map (scale it!, resolution)
3. Basic map elements:
    1. Legend
    2. Title
    3. Sources
    4. Authorship
    5. Date





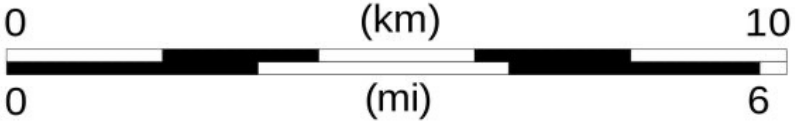
Parts of a map

1. data (or map) frame
2. map legend
3. map title
4. north arrow
5. map scale bar
6. metadata (or map citation
7. border (or neatline)
8. inset (or locator) map



Types of map scales

- **Verbal scale**: 1 inch = 2000 feet (1" = 2000')
- **Ratio scale**: 1:24,000
- **Bar scale**: graphical representation with bar lengths and number labels



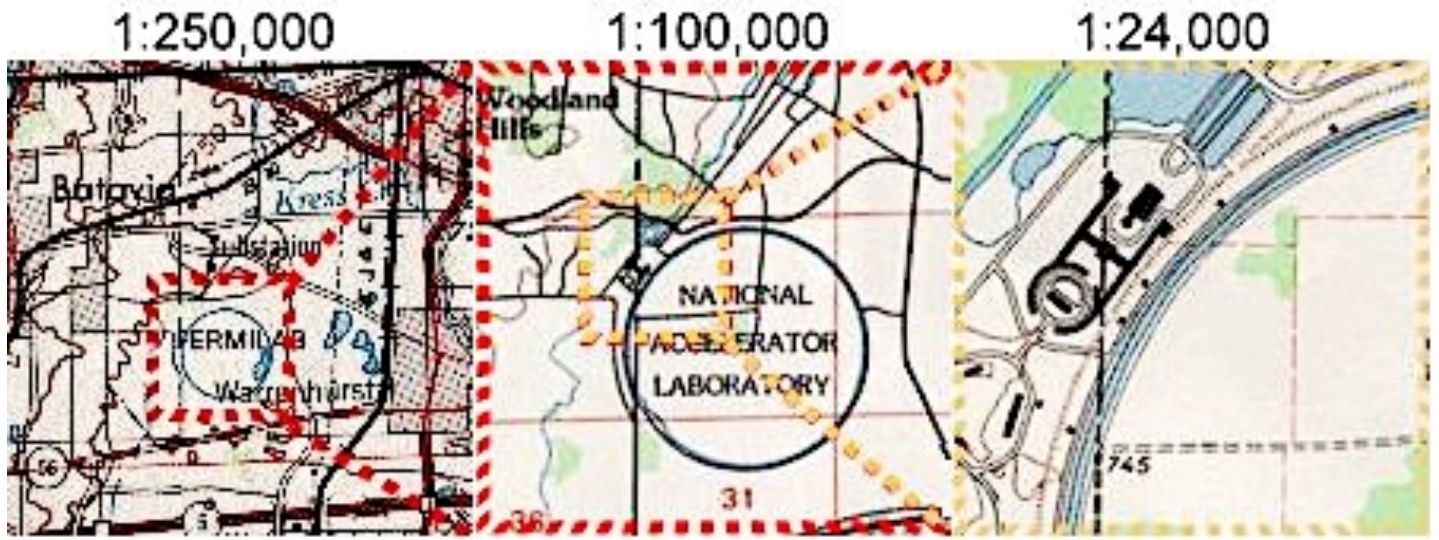
  - Valid after photographic reduction or enlargement
  - Convert between types
- Different ratios show varying detail and area in maps.
  - For instance:

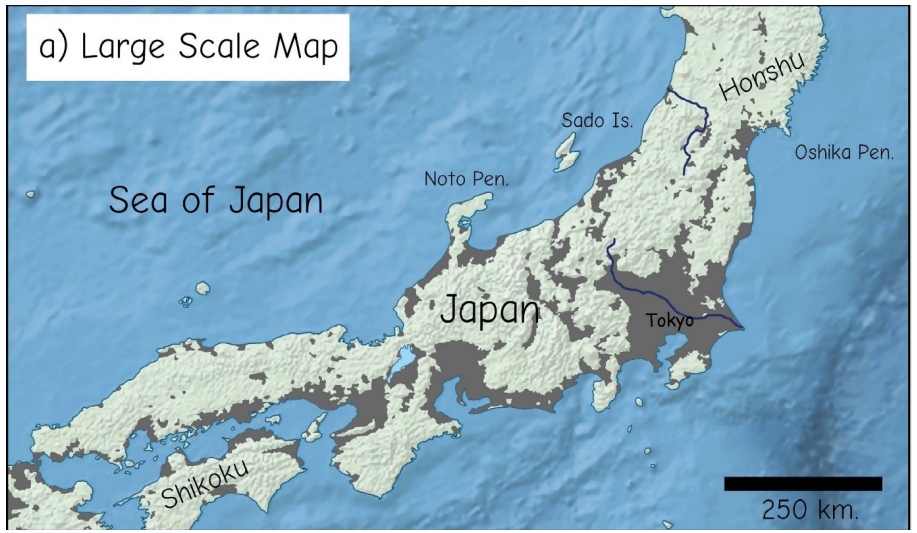
    1 : 63,360 (less detail, more area)
    1 : 12,000 (more detail, less area)
    1 : 20 (more detail, less area)

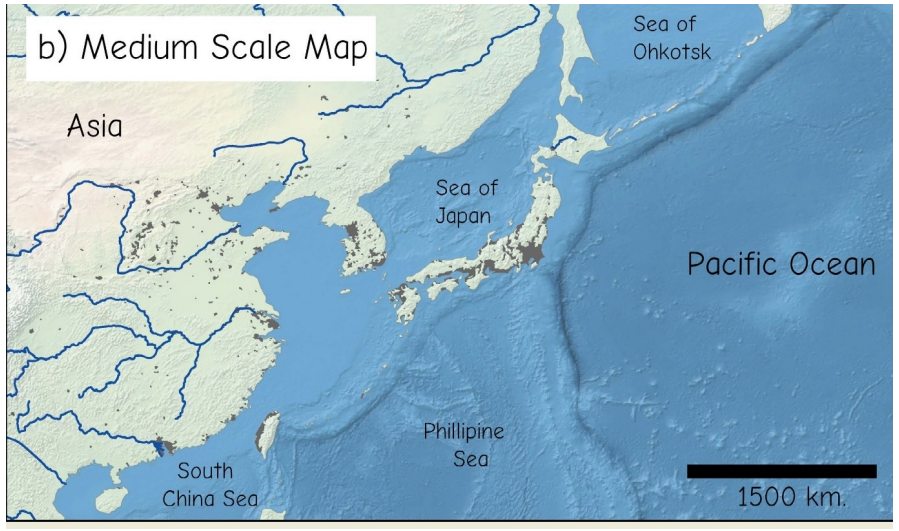
Small ← Map scale → Large

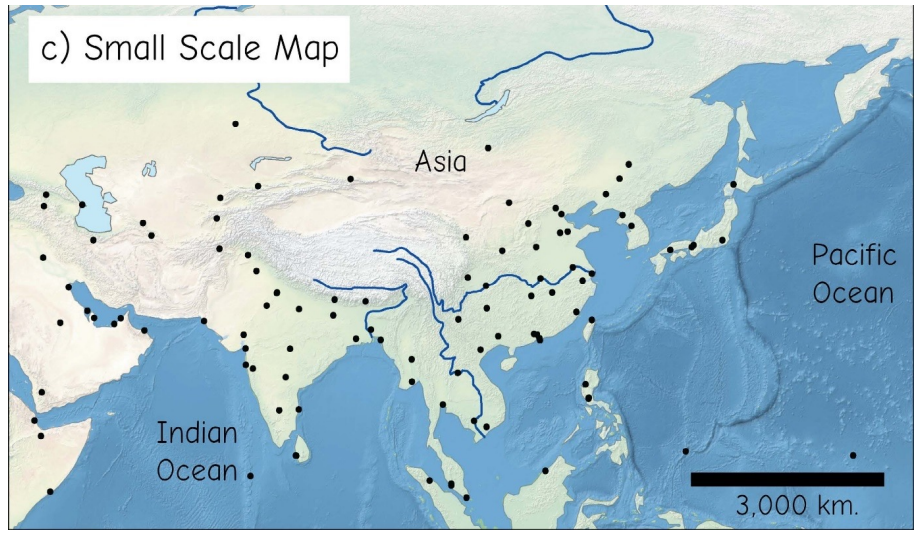
Large ← Mapped earth area → Small

Less ← Information detail → More




a) Large Scale Map
Honshu
Sado Is.
Oshika Pen.
Noto Pen.
Sea of Japan
Japan
Tokyo
Shikoku
250 km.


b) Medium Scale Map
Sea of Ohkotsk
Asia
Sea of Japan
Pacific Ocean
Phillipine Sea
South China Sea
1500 km.


c) Small Scale Map
Asia
Pacific Ocean
Indian Ocean
3,000 km.

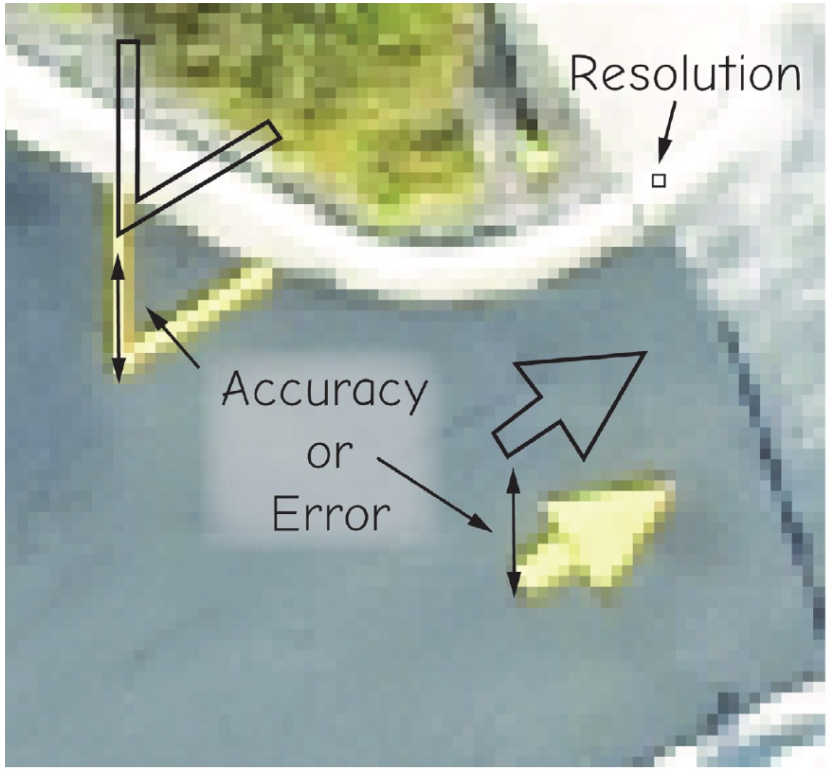
Scale issue: ERROR

- The surface error caused by a 1-millimeter digitizing or map error will change as scale changes. Note the larger error at smaller scales.

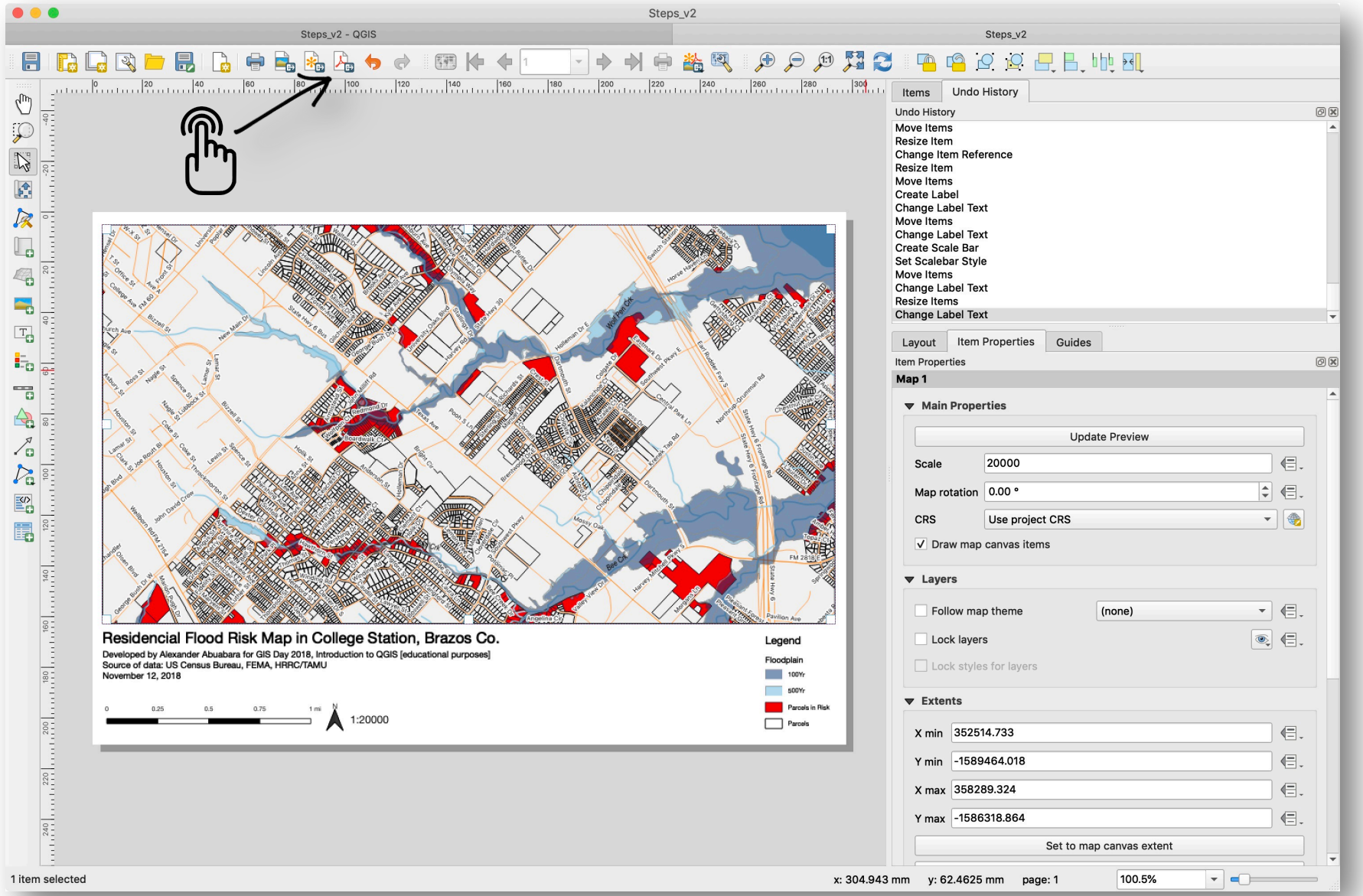
Scale	Error (m)	Error (ft)
1:24,000	24	79
1:50,000	50	164
1:62,500	63	205
1:100,000	100	328
1:250,000	250	820
1:1,000,000	1,000	3,281

Accuracy vs. resolution

- Resolution is the smallest spatial unit mapped
- **Accuracy is the difference between encoded and actual value**

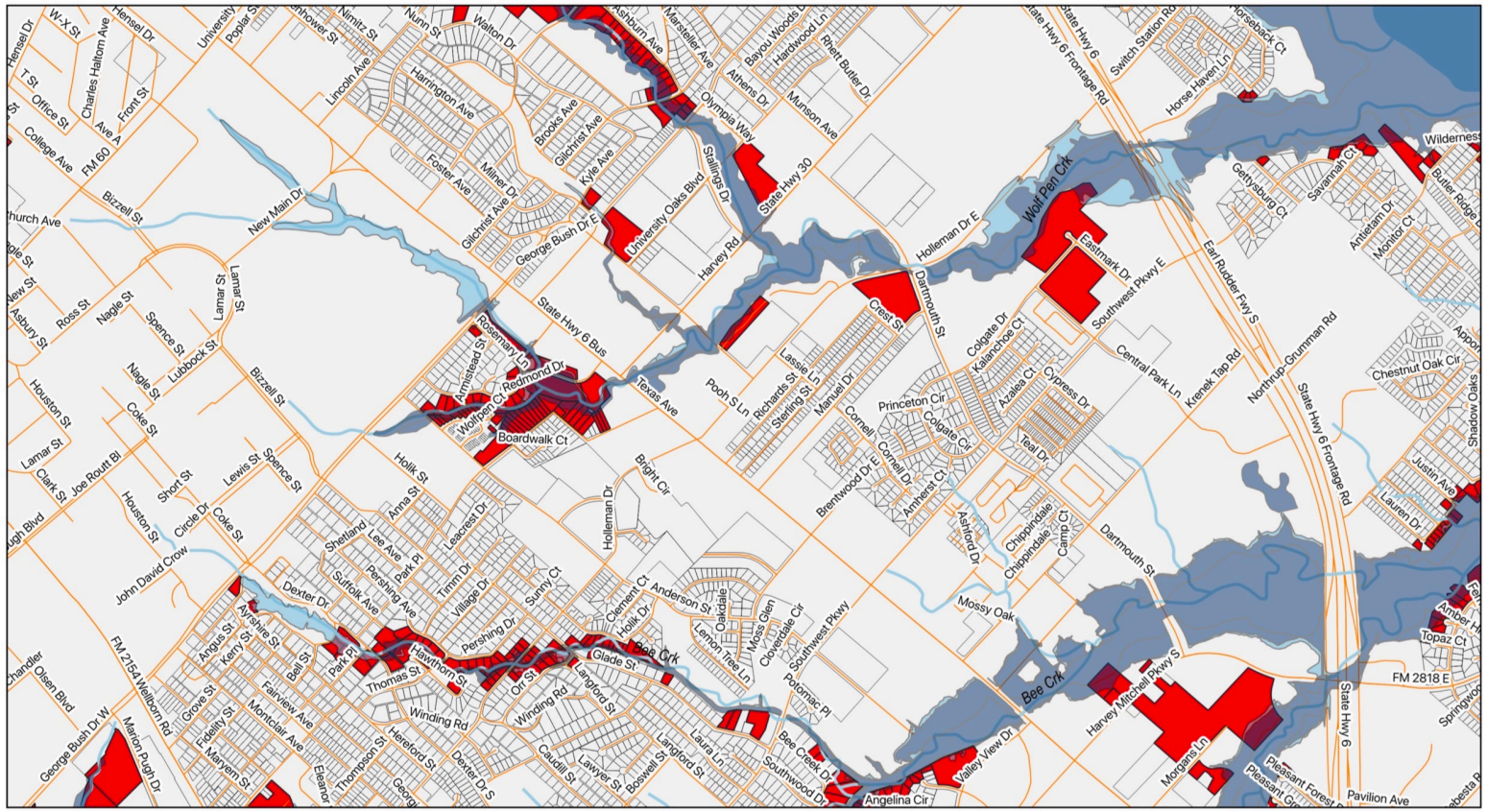


Final result should be similar to this ...



PDF Export

Steps_v2.pdf (1 page)



Residencial Flood Risk Map in College Station, Brazos Co.

Developed by Alexander Abuabara for GIS Day 2018, Introduction to QGIS [educational purposes]
Source of data: US Census Bureau, FEMA, Brazos Central Appraisal District, HRRC/TAMU
November 12, 2018

0 0.25 0.5 0.75 1 mi

N

1:20000

Legend

Floodplain
- 100Yr
- 500Yr

Parcels
- Residencial Parcels in Risk
- Residencial Parcels

Acknowledgements

THANK YOU!

- The **QGIS community** for constant development and support of the software.
- Dr. **Daniel Goldberg** for getting me involved in.
- **All people** involved in organizing the **Tx GIS Day** for which this material was developed.
- The **Wm Michael Barnes Department of Industrial & Systems Engineering** which I am part.

"To the children
the restless sea with its many changes was a new sight."

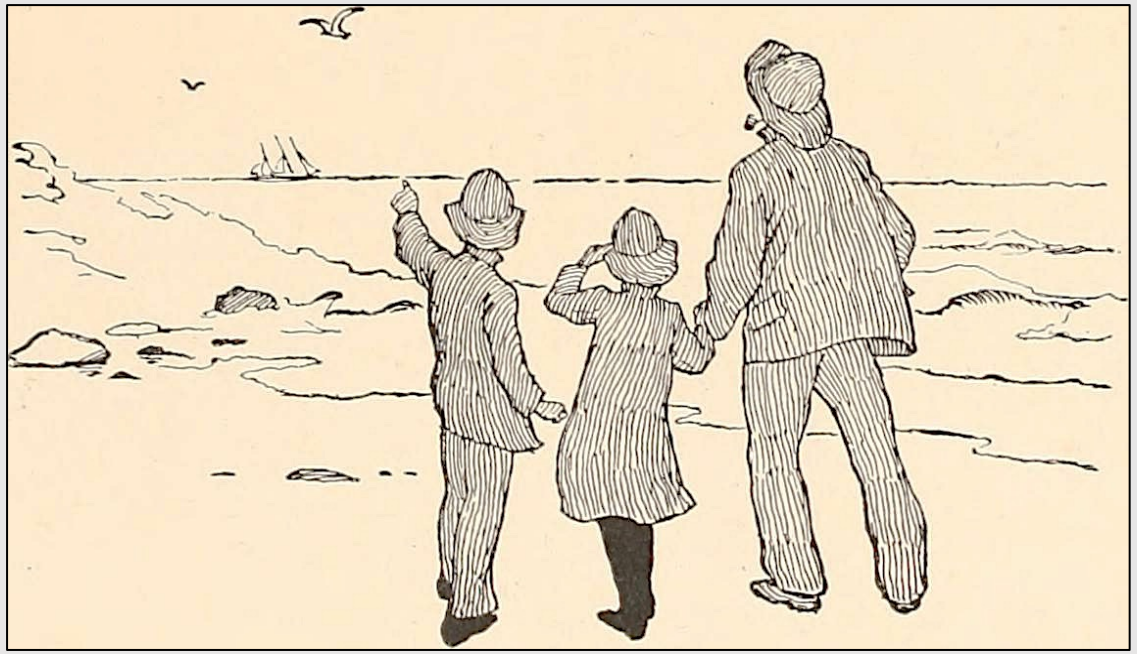
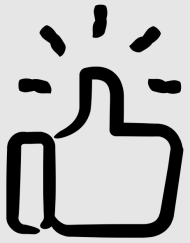


Image and text from page 33 of
"The Seashore Book: Bob and Betty's summer with Captain Hawes" (1912)



Data Source

1. https://www.brazoscad.org/gis/
2. https://earthexplorer.usgs.gov
3. https://www.fema.gov/national-flood-hazard-layer-nfhl
4. https://www.census.gov/geo/maps-data/data/tiger-line.html