GIS Level 2: Introduction to Spatial Analysis

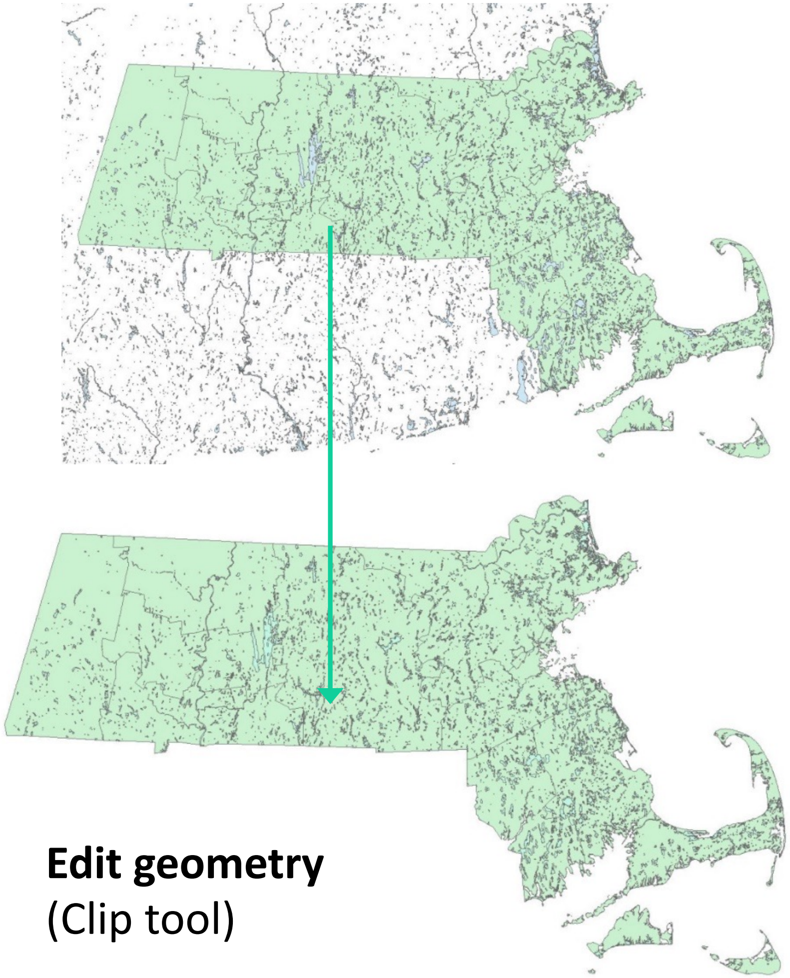
OUTLINE

- Introduction to spatial analyses
- Use map projections & metadata to understand and transform spatial data
- Use different types of processing tools in software(s) to perform a multi-step analysis
- Exercise new knowledge with GIS software(s)

Introduction » Map Projections » Metadata » Processing Tools » Exercise

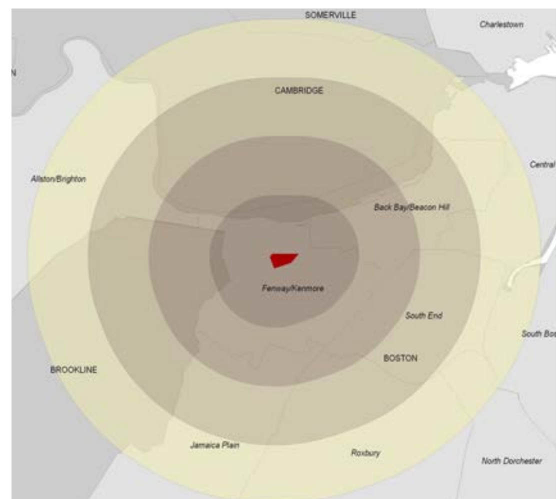
INTRODUCTION TO SPATIAL ANALYSIS

What analyses can you do?



Edit geometry
(Clip tool)

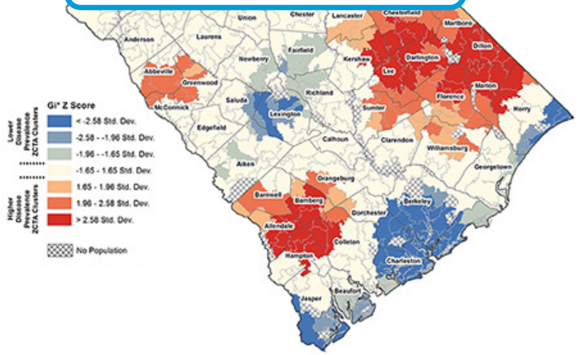
Analyze values
(Vectors)
(Rasters)



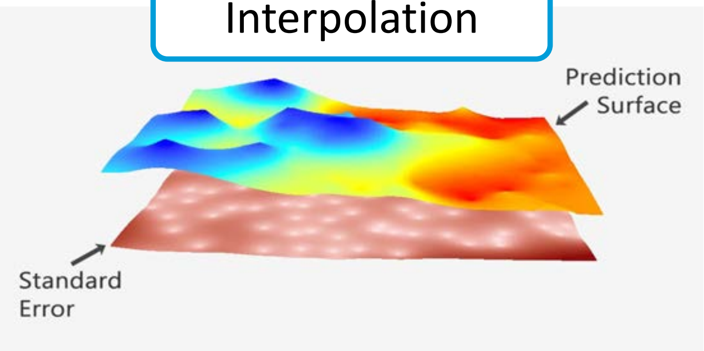
Create data
(Buffer tool)

Specialized tools are used to quantify patterns & relationships in your data.

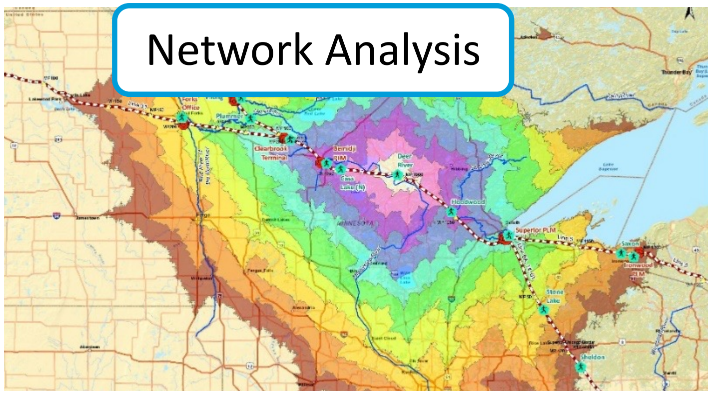
Spatial Statistics



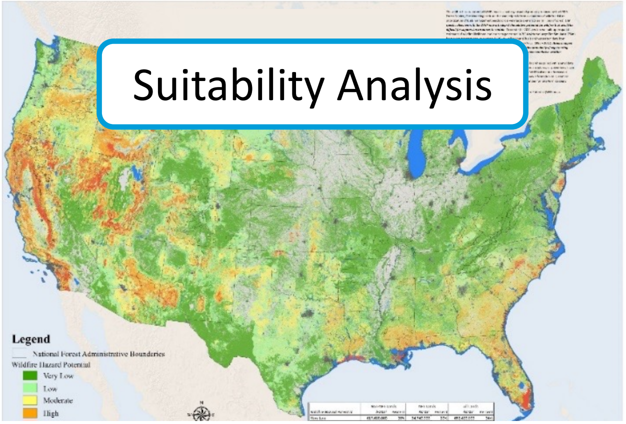
Interpolation



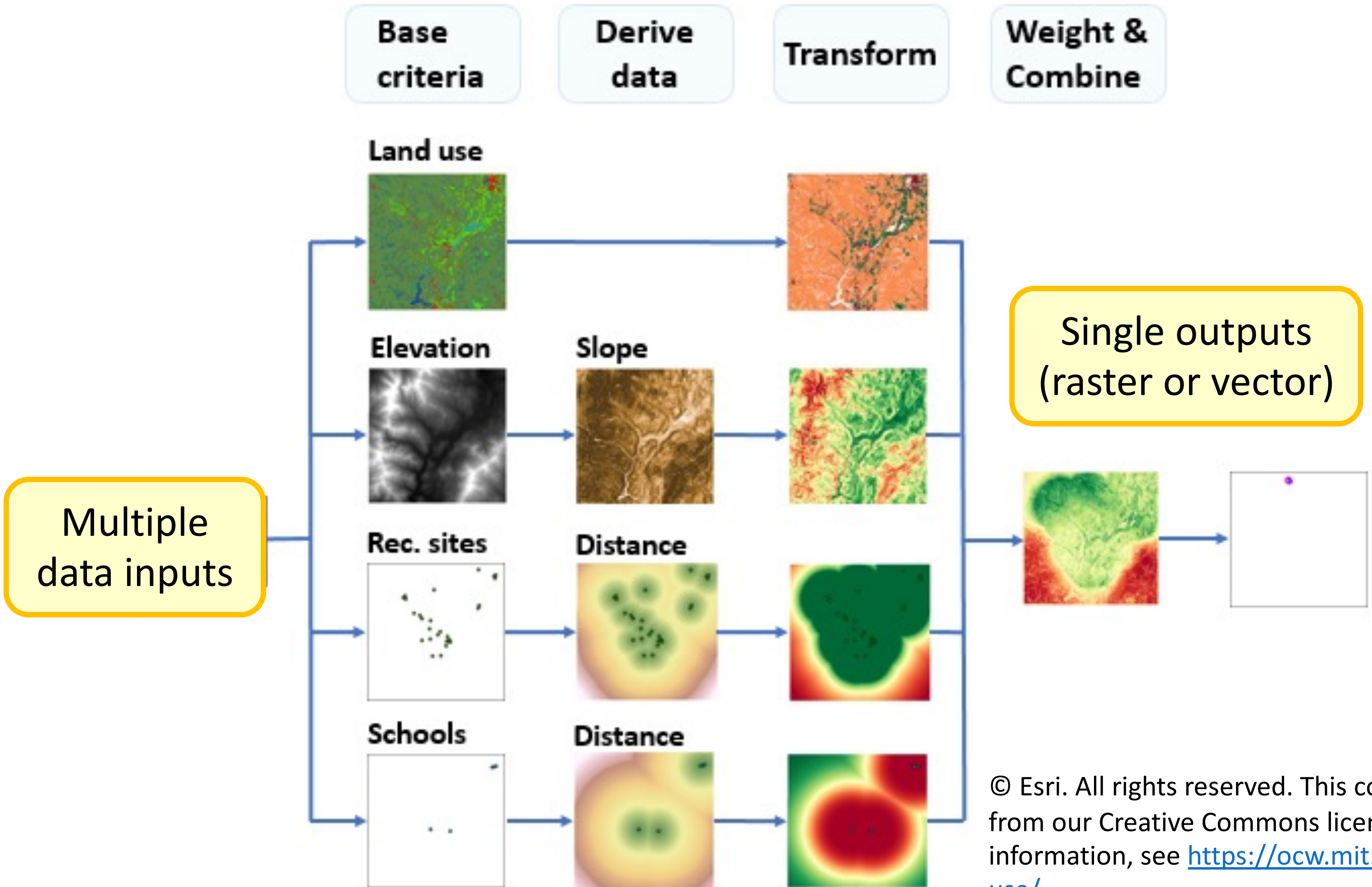
Network Analysis



Suitability Analysis



Multiple tools are often used together.

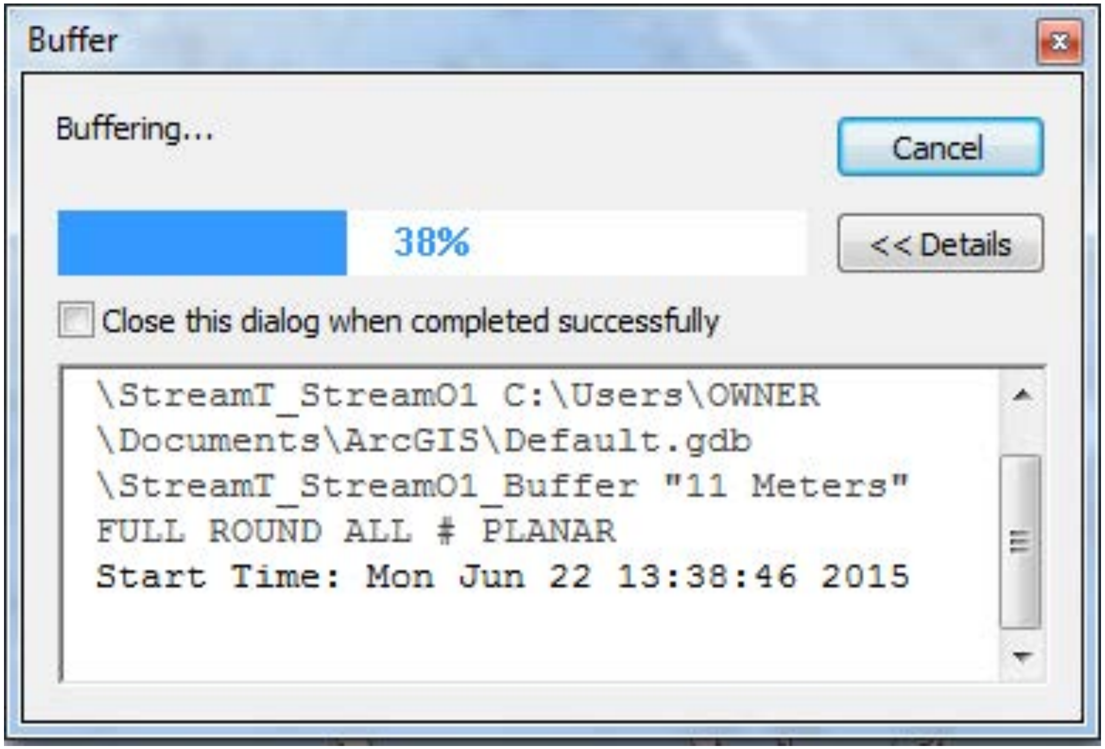


MAP PROJECTIONS:
WHY DO WE CARE ABOUT THEM?

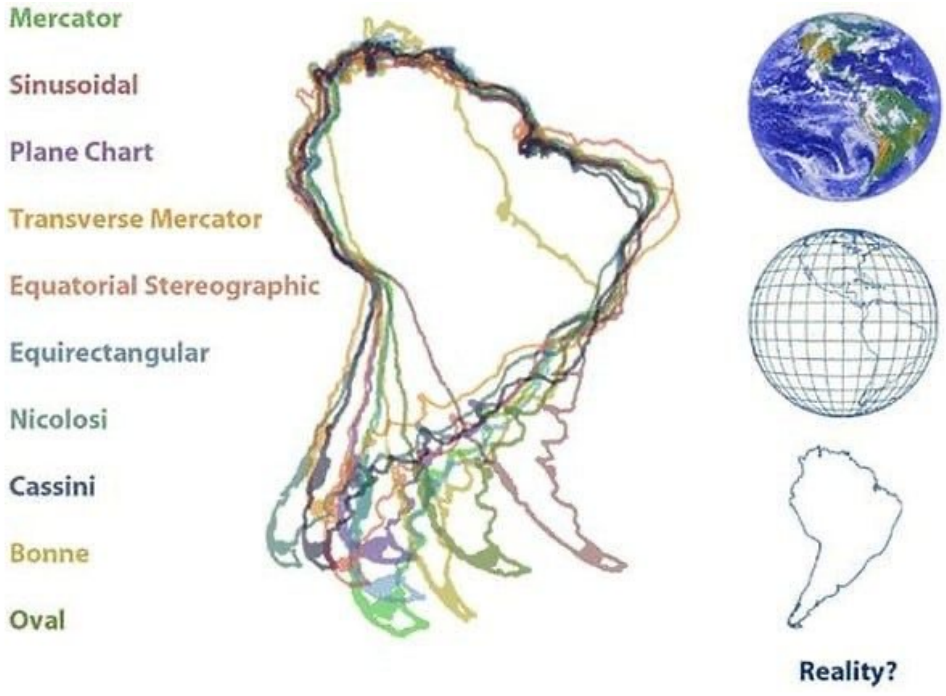
If a coordinate system is wrong or missing, data will not display in the correct location.

https://ihatecoordinatesystems.com/

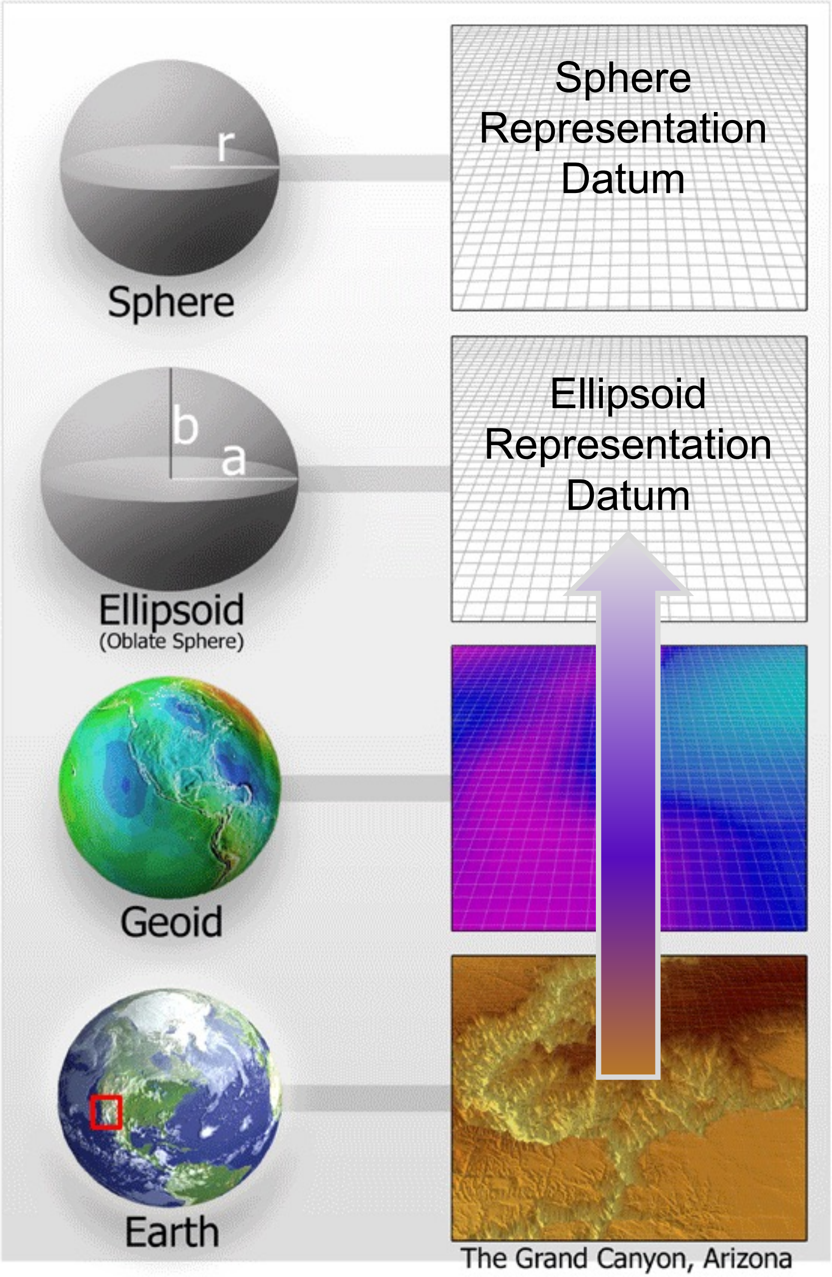
Using the same projection for all the datasets in your project will lead to faster processing time.



Analysis tools that involve shape, area, direction, form, or distance calculations require data to be in a suitable projected coordinate system.



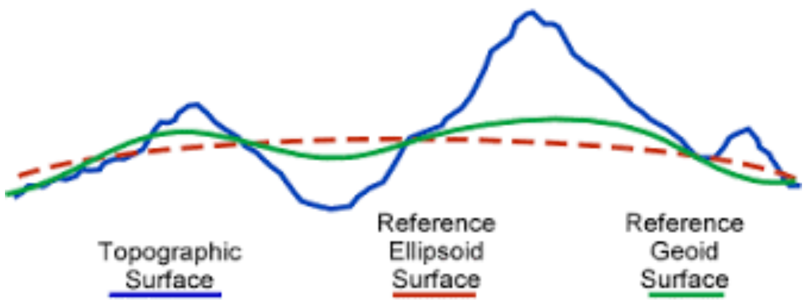
MAP PROJECTIONS:
WHAT ARE THEY?



A Geographic Coordinate System (GCS) consists of

- Datum
- Prime Meridian
- Angular Unit

A Datum is an idealized mathematical representation of the Earth.

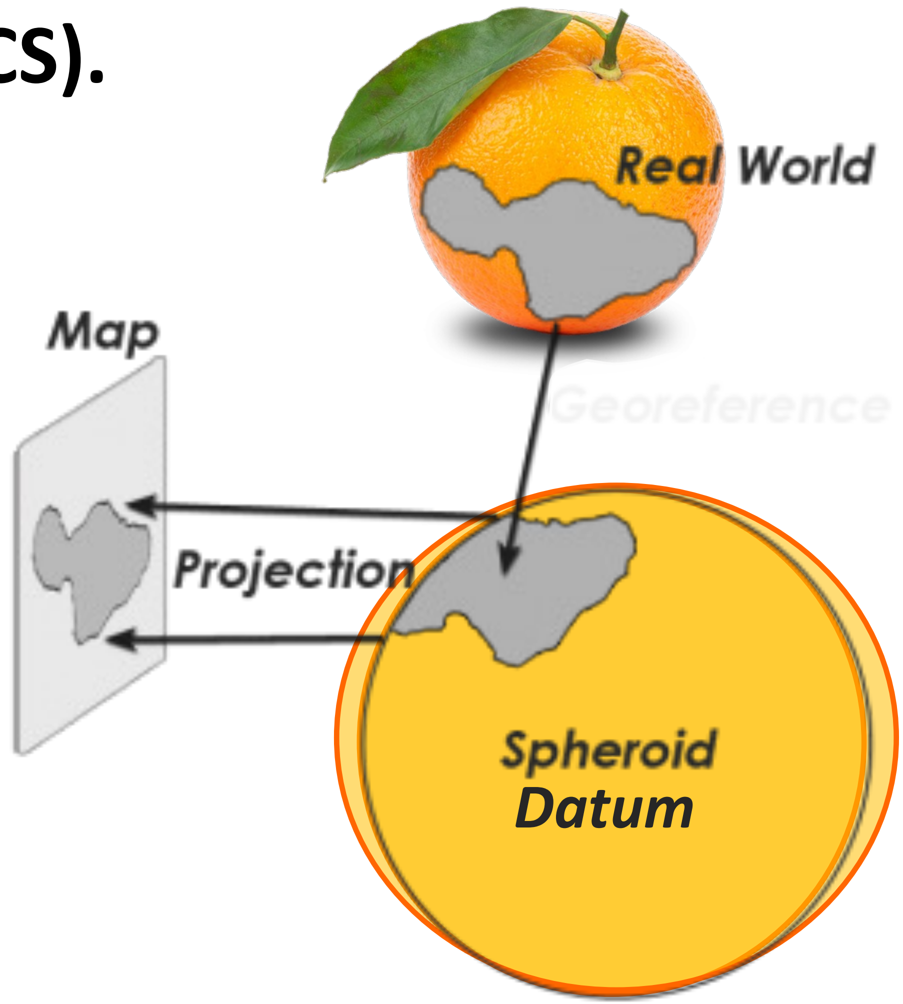


http://desktop.arcgis.com/en/arcmap/latest/map/projections/what-are-map-projections.htm

A projection algorithm is applied to the GCS to create a Projected Coordinate System (PCS).

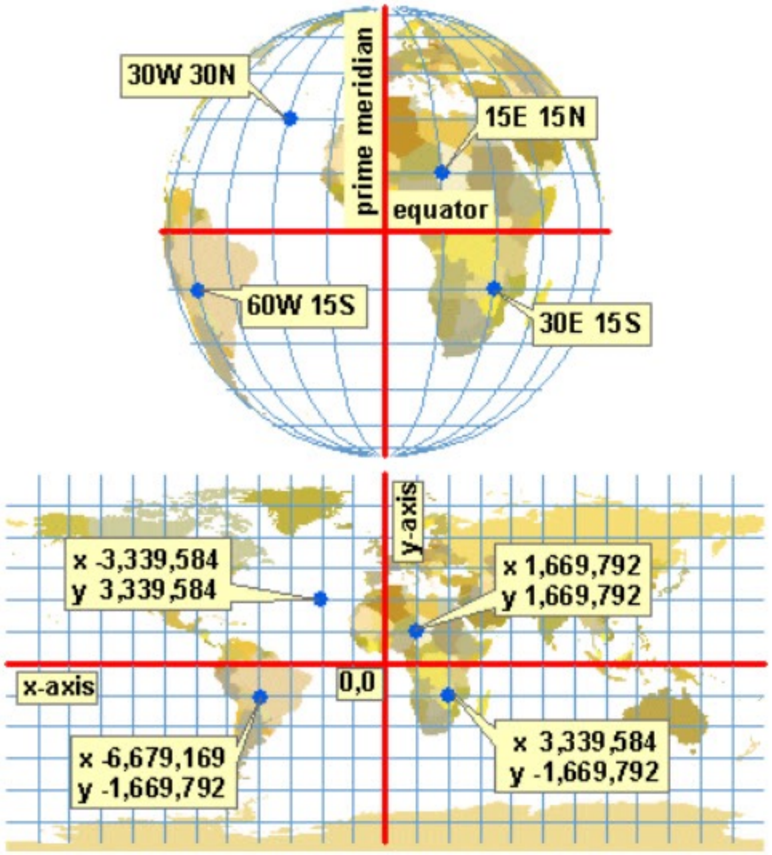
Imagine an orange as the Earth, and you want to be able to peel it in such a way as to lay the peel flat.

Similarly, **projection is a method by which cartographers translate a 3D globe (spheroid or ellipsoid) to a 2D map surface.**

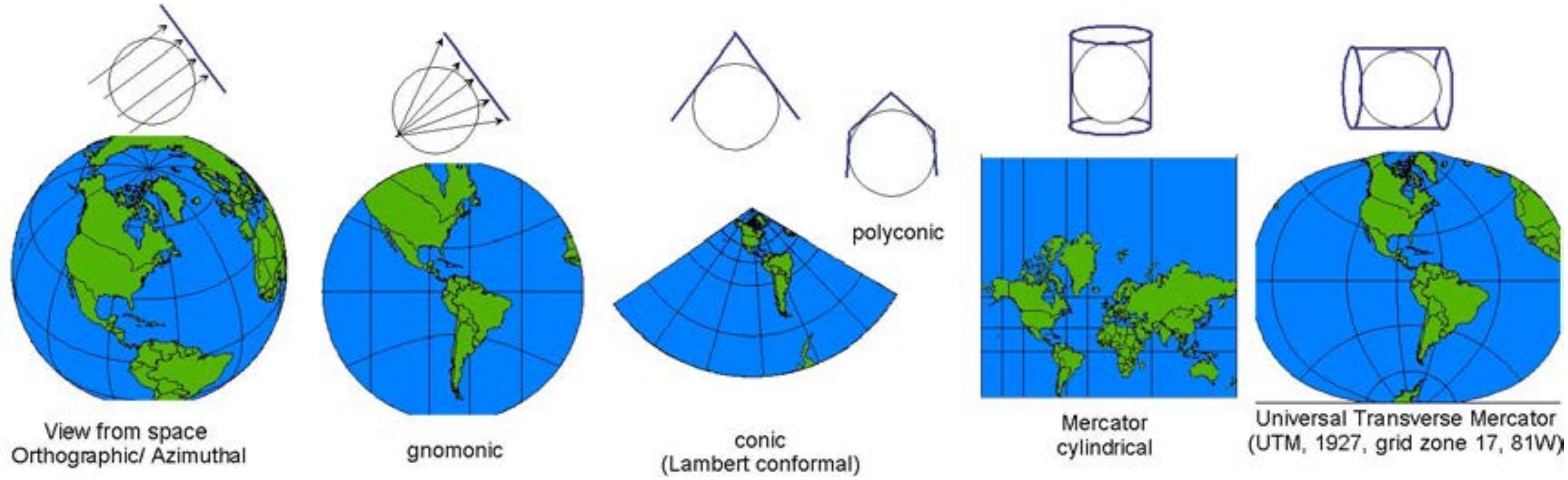


A Projected Coordinate System consists of

- Geographic Coordinate System
- Projection Algorithm
- Linear Unit
- Parameters that center the system on a certain location



There are many different types of projections. Each have certain strengths and limitations in the following types of distortions: shape, area, distance, direction



Coordinate Systems Characteristics

Geographic

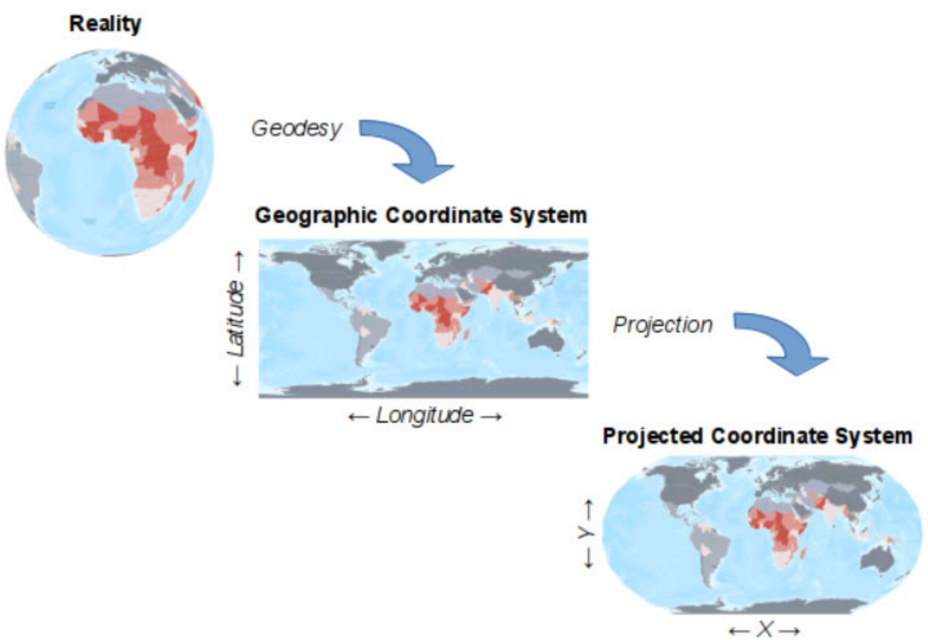
- 3D spherical/spheroidal surface defines locations
- Units: degrees (angular)
- Lengths, angles, and areas change with distance away from equator

Projected

- 2D flat/planar surface defines locations
- Units: ft, m, miles, etc. (linear)
- Lengths, angles, and areas constant across the two dimensions

Coordinate Systems Summary

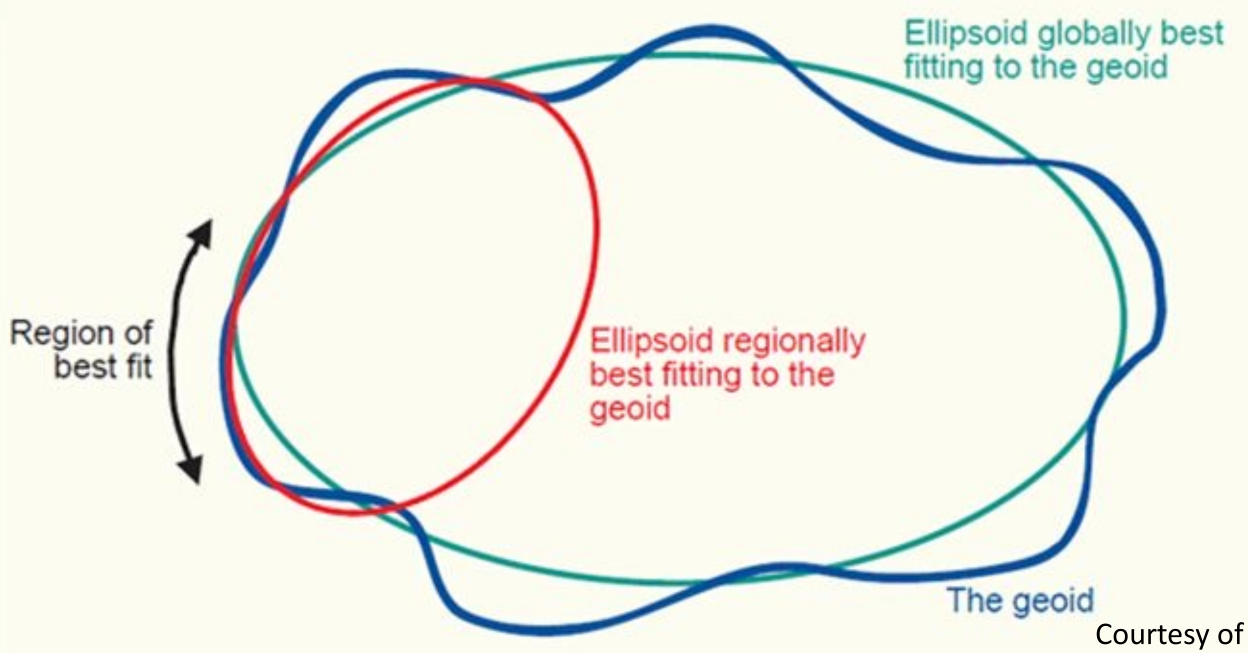
1. Data often start in a geographic coordinate system.
2. They are projected into a projected coordinate system.
3. The projection depends on the data location and analyses

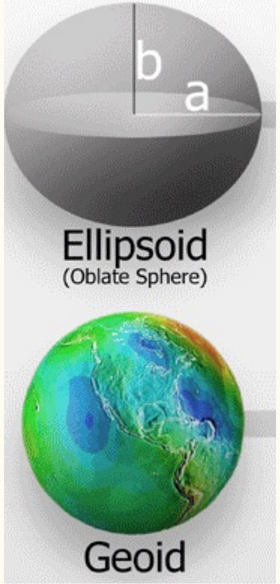


Commonly Encountered Systems

Geographic Coordinate System

- NAD83 (North American Datum) – best fitting ellipsoid for North America
- WGS1984 (World Geodetic System) – best fitting ellipsoid for the globe/world

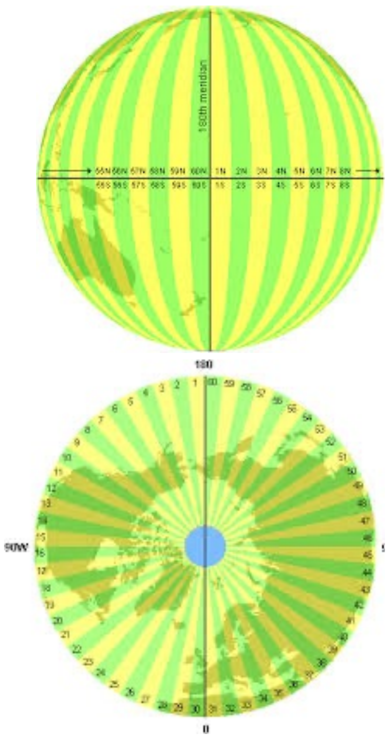


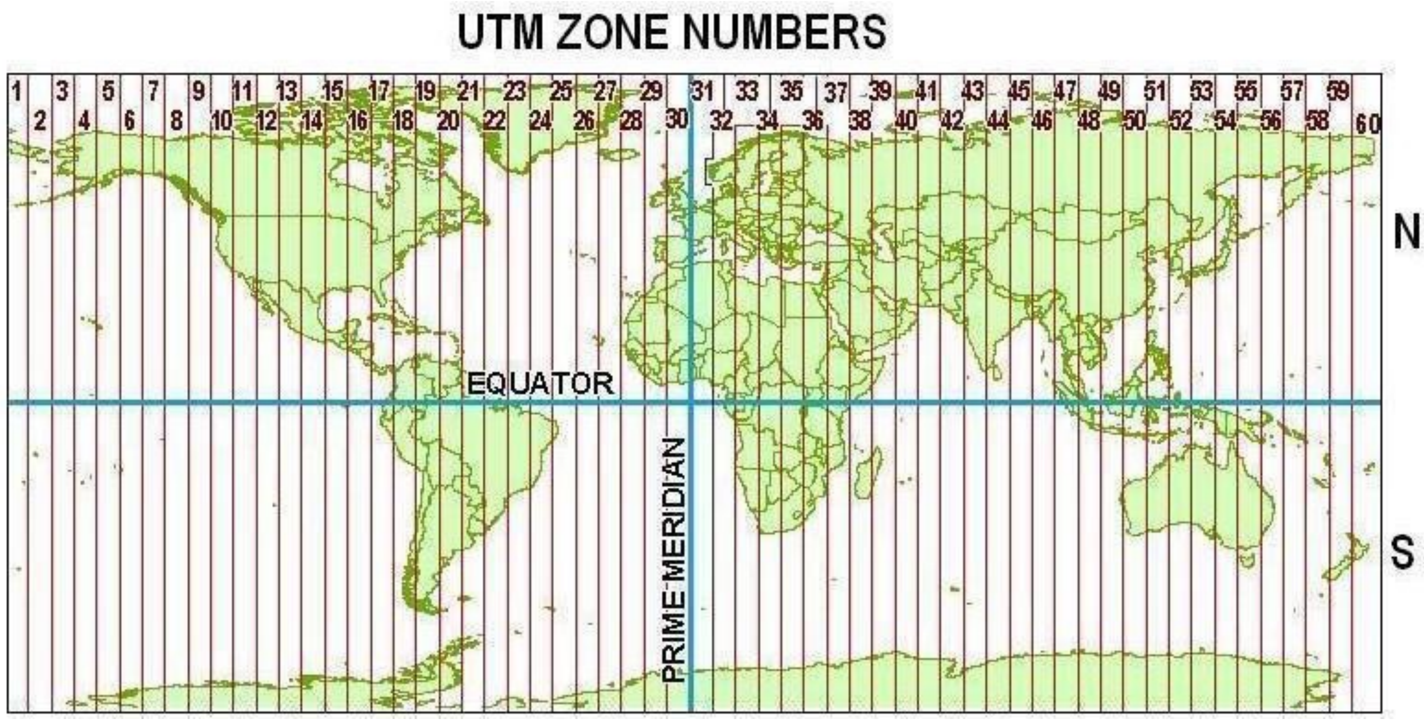


Commonly Encountered Systems

Projected Coordinate System

- UTM (Universal Transverse Mercator) – often best for large regions

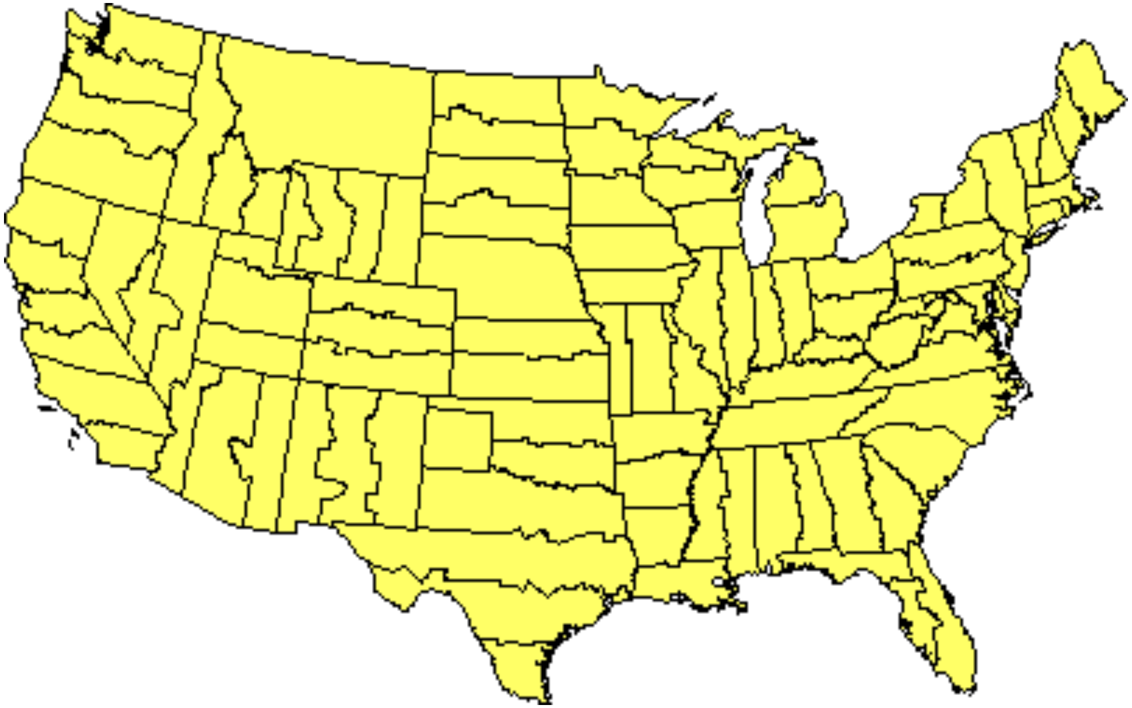




Commonly Encountered Systems

Projected Coordinate System

- USA State Plane Systems – have been optimized per state, see updates here.



Tips on selecting a Projected Coordinate System

- **Based on your project's analyses:**
  - Preserve **area** with equal-area projections
  - Preserve **shape** with conformal projections
  - Preserve **direction** with azimuthal projections
  - Preserve **distance** with equidistant projections
  - Other projections compromise on the distortions
  - (Usually you stick with one, but can re-project)

Tips on selecting a Projected Coordinate System

- **Based on your project's location:**

  Size

  – Locally, the US has 'state plane systems'

  – Regionally, UTM is often a good option

  – World, World Mercator (EPSG: 3857)

  Region

  – To map tropical regions, use a cylindrical projection 

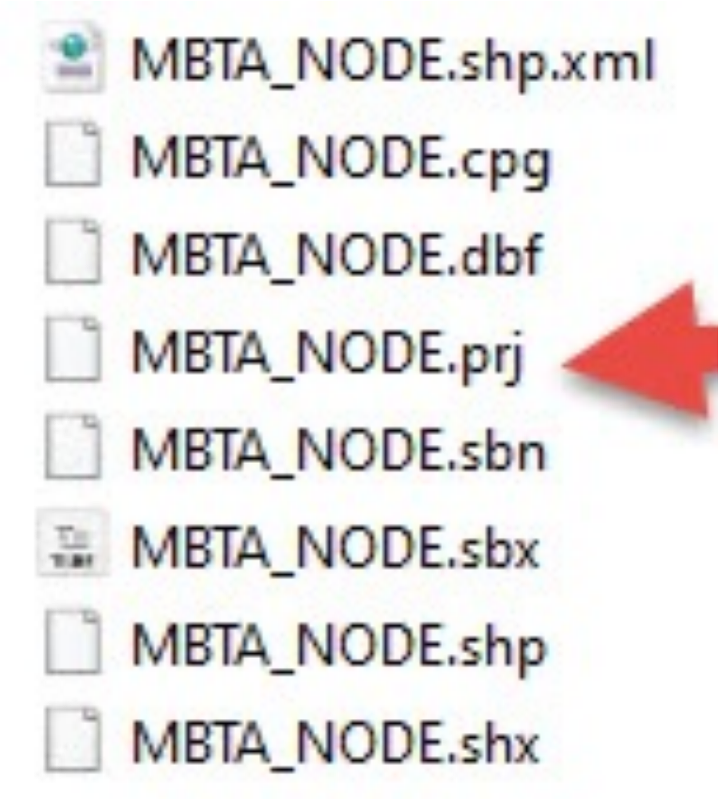
  – To map middle latitudes, use a conic projection 

  – To map a polar region, use an azimuthal projection 

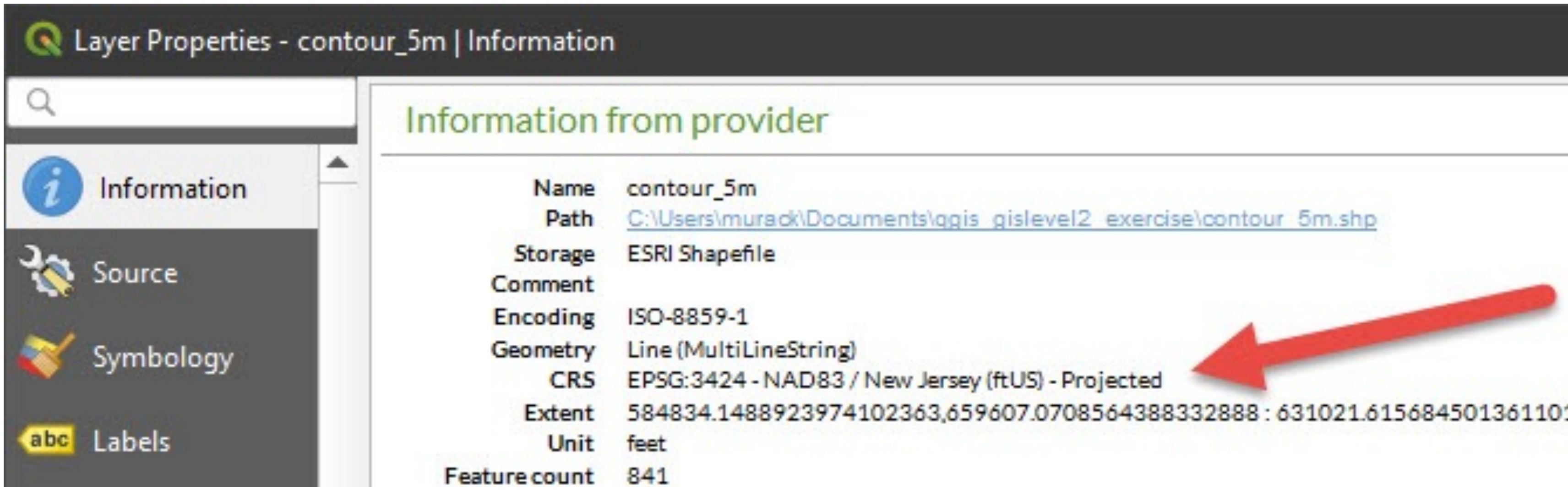
MAP PROJECTIONS:

HOW DO YOU KNOW THE COORDINATE SYSTEM OF YOUR DATA?

Option 1: Look for a .prj (projection) file within the files that make up the “shapefile” and then…



Option 1 continued: Open the file in QGIS or ArcGIS and examine the data layer information.



Note: ESRI products (ArcGIS Desktop and ArcGIS Pro) refer to geographic & projected coordinate systems with names while QGIS uses EPSG codes:
NAD 1983 StatePlane New Jersey FIPS 2900 (US Feet) versus EPSG: 3424

Option 2: Consult the metadata

Spatial Reference Information

Horizontal Coordinate System Definition

Geographic Coordinate Units	Decimal degrees
Latitude Resolution	0.000000
Longitude Resolution	0.000000
Horizontal Datum Name	D_WGS_1984
Ellipsoid Name	WGS_1984
Semi-major Axis	6378137.000000
Denominator of Flattening Ratio	298.257224

Geographic Coordinate System in WGS84

Entity and Attribute Information

Distribution Information

Exercise 1: Coordinate Systems

Goals

- Learn how to transform a coordinate system in GIS software

Steps

- Open either the QGIS or ArcGIS Pro.
- You will now choose a breakout rooms and be guided through the first exercise.

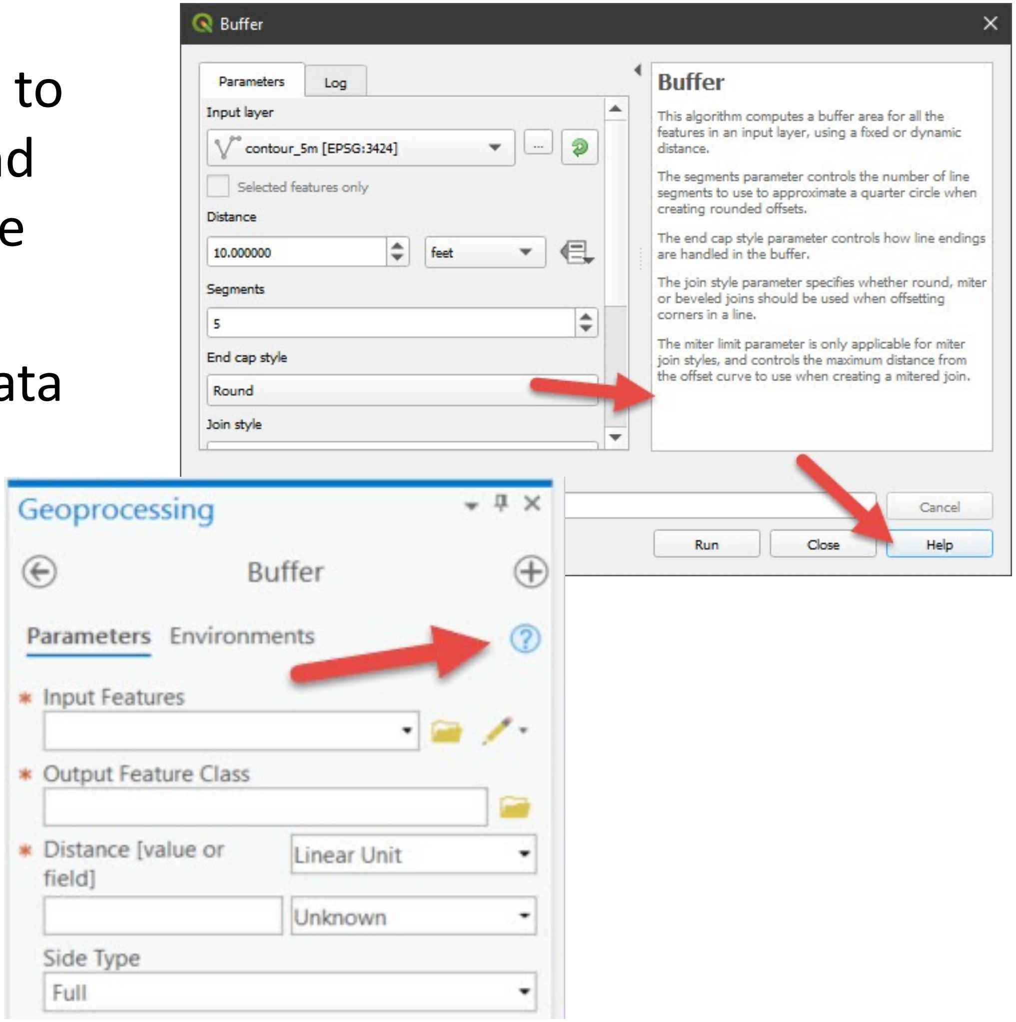
PROCESSING TOOLS: OVERVIEW

Use processing tools to:

"capture, store, check, integrate, manipulate, analyze and display geospatial data"

Tool considerations

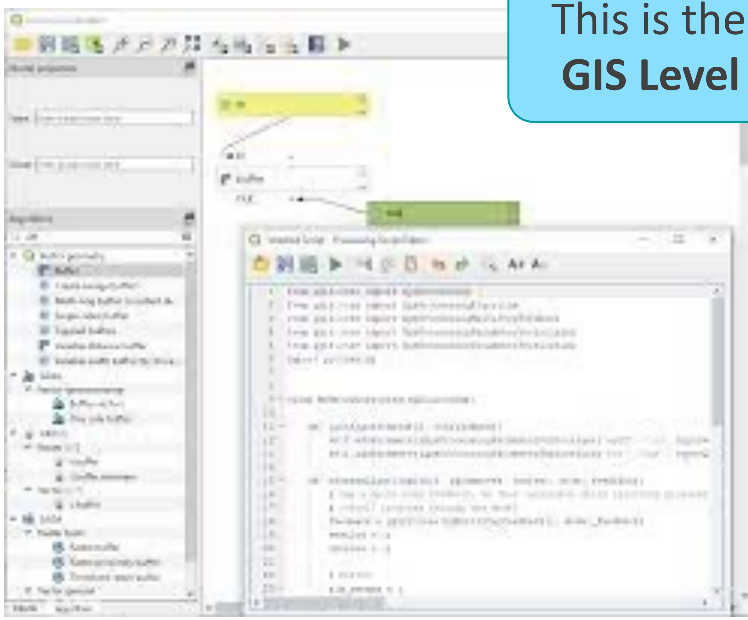
- Read the tool help resource to understand how it works and determine if it is appropriate for your data.
- The accuracy of the input data determines the accuracy of the results.



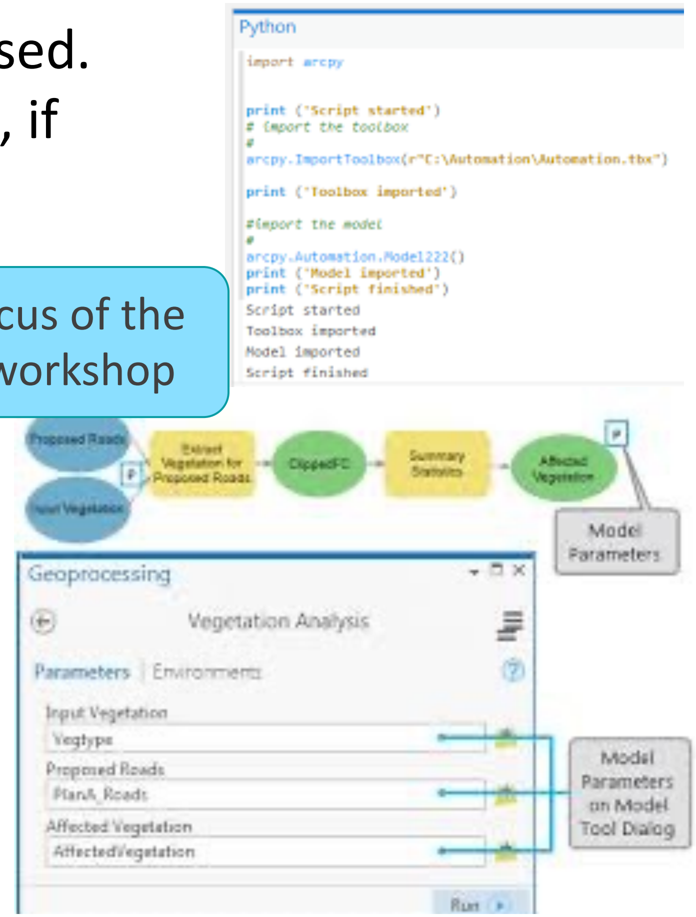
Batch tools

Record tools, inputs, and parameters used. Export this information as python code, if possible, so results can be replicated.

This is the focus of the **GIS Level 3** workshop



QGIS: Graphical Modeler & Python



ArcGIS Pro: Model Builder & Python

PROCESSING TOOLS: ARCGIS PRO VS QGIS

Analysis Tools

ArcGIS Pro (by ESRI)

- Can easily import all data types (raster, vector, tabular)
- Full set of GIS functions & tools (depends on licensing level)
- Comprehensive support (direct support from ESRI, access to online modules and tutorials, and documentation for every tool)

QGIS

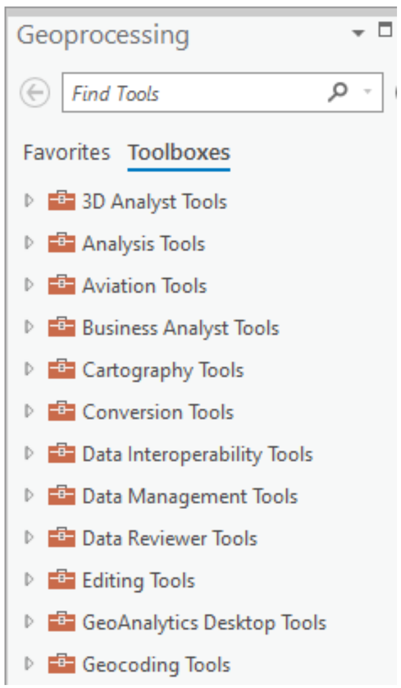
- Can easily import all data types (raster, vector, tabular, & more)
- Many available tools, but lacking some advanced analyses: network analysis, spatial statistics
- Tools can be developed by anyone so performance & documentation can be inconsistent.
  - Support via forums, eg StackExchange

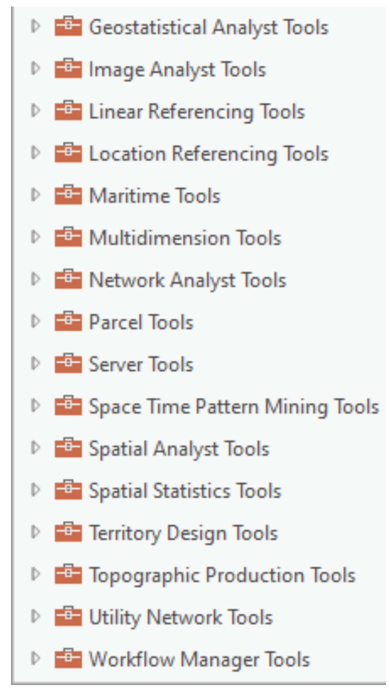
Both have similar interfaces
and many of the same analysis tools.

PROCESSING TOOLS: ARCGIS PRO

ArcGIS Pro Analysis Tools

ArcGIS Pro offers a variety of toolboxes that contain tools that work on certain types of data or perform specific types of analysis.





ArcGIS Pro Extensions

Advanced Analysis

- 3D Analyst
- Business Analyst
- Geostatistical Analyst
- Image Analyst
- Network Analyst
- Spatial Analyst

Used most often

Industry Focused

- Aviation Airports & Charting
- Defense Mapping
- Maritime
- Pipeline Referencing
- Production Mapping
- Roads and Highways

Data and Workflows

- Data Interoperability
- Data Reviewer
- Indoors
- LocateXT
- Publisher
- StreetMap Premium
- Territory Design
- Workflow Manager
- Workflow Manager (Classic)

PROCESSING TOOLS: QGIS

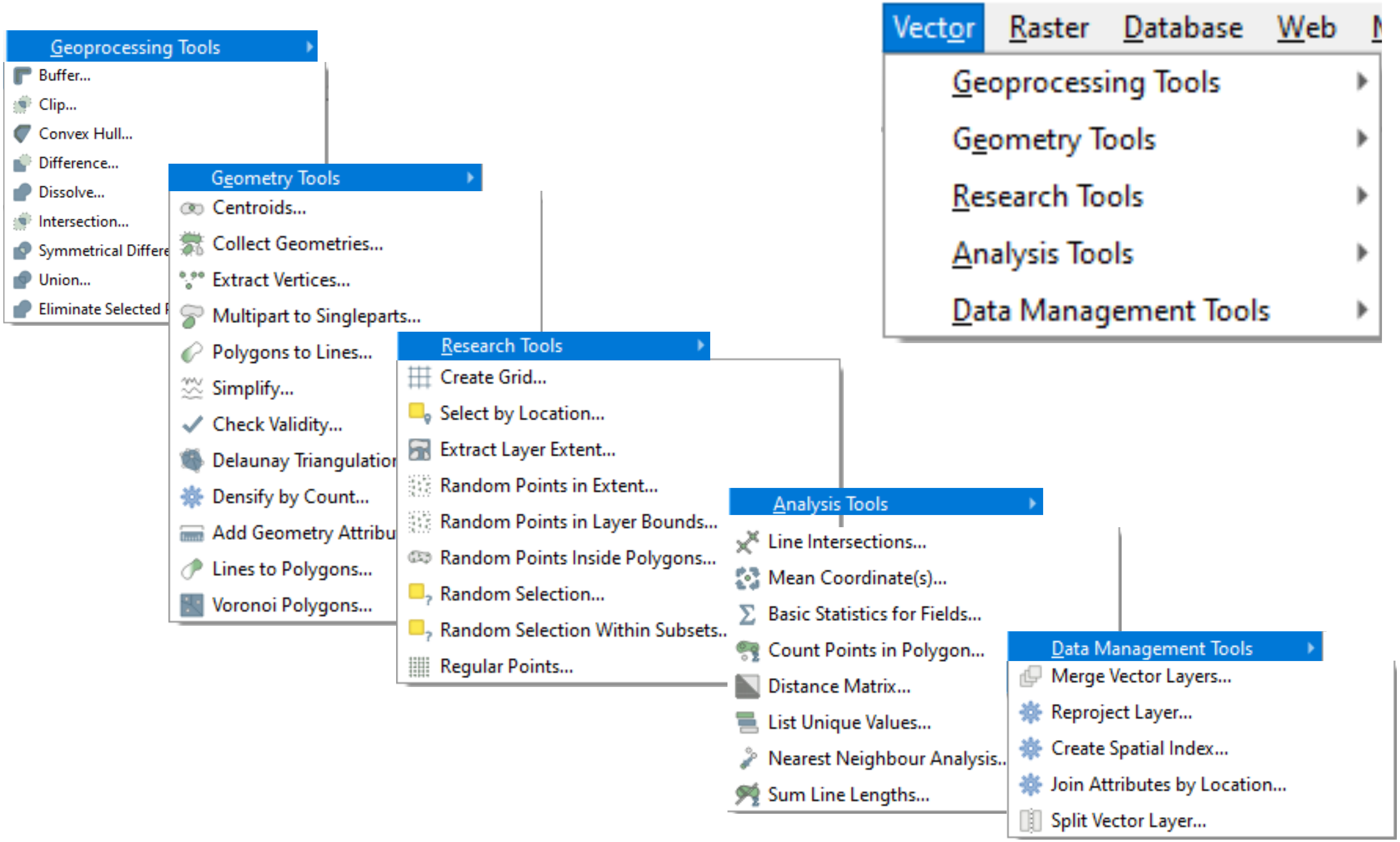
QGIS Analysis Tools

QGIS offers vector analysis, raster analysis, sampling, geoprocessing, geometry, & database management tools.

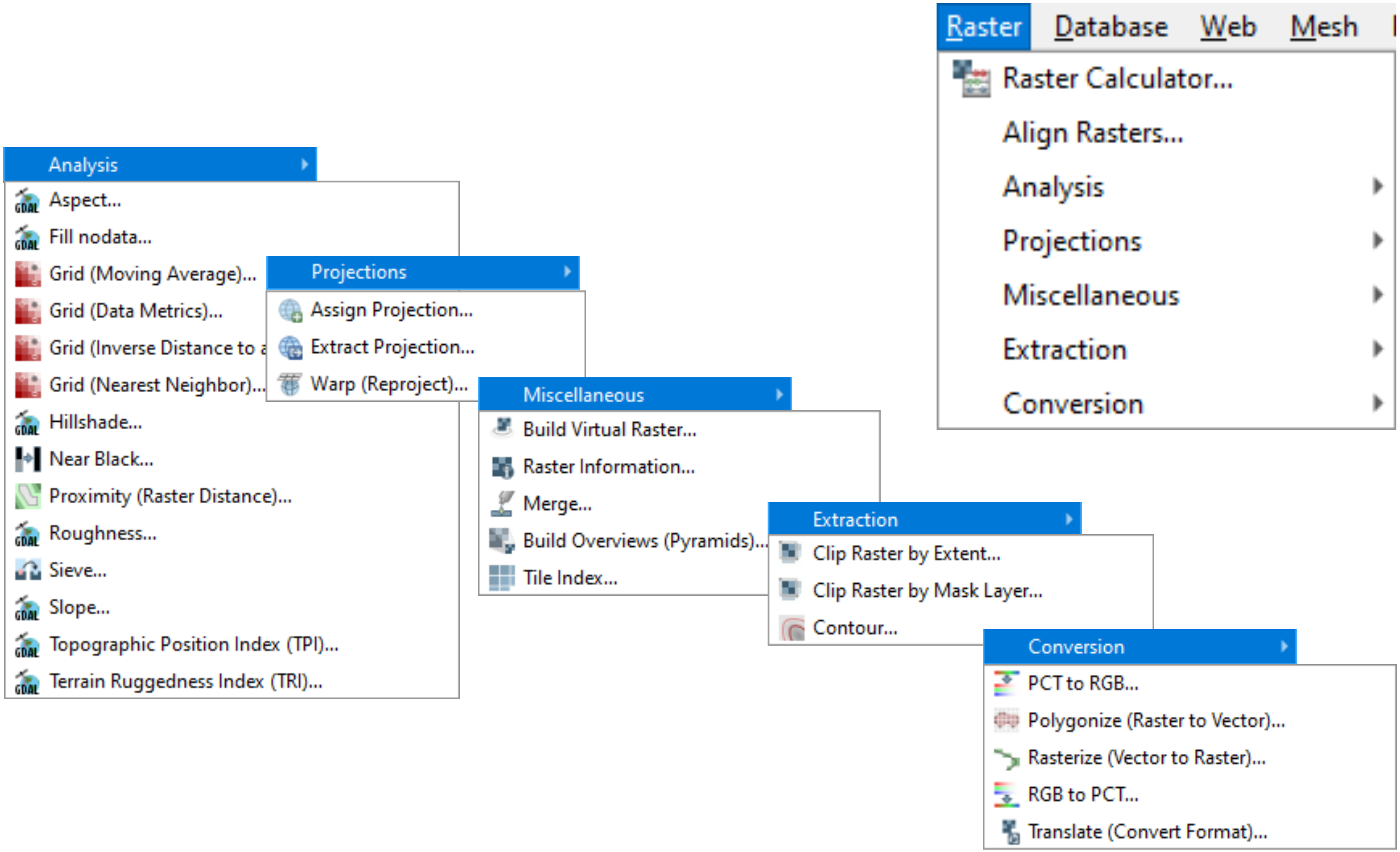
Additional tools include:

- **Integrated GRASS tools** with more than 400 modules.
- **Processing plugin**, a powerful geospatial analysis framework to call native and third-party algorithms from QGIS, such as GDAL, SAGA, GRASS, R, etc.
- **Extensible plugin architecture**, can extend QGIS functionality where libraries can be used to create your own plugins.

QGIS Vector Analysis Tools



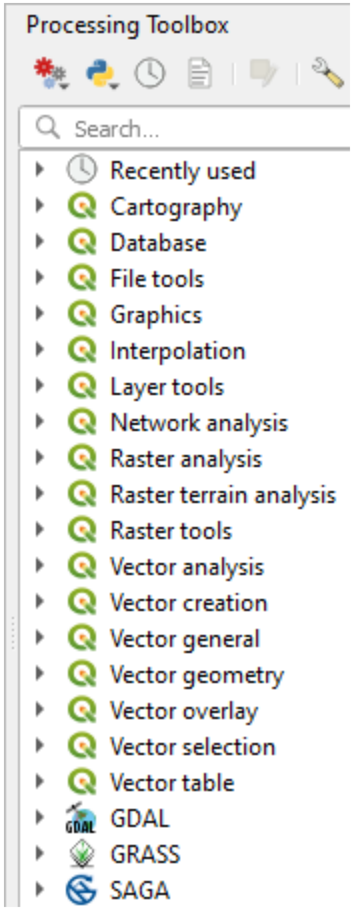
QGIS Raster Analysis Tools



QGIS Processing Plugin

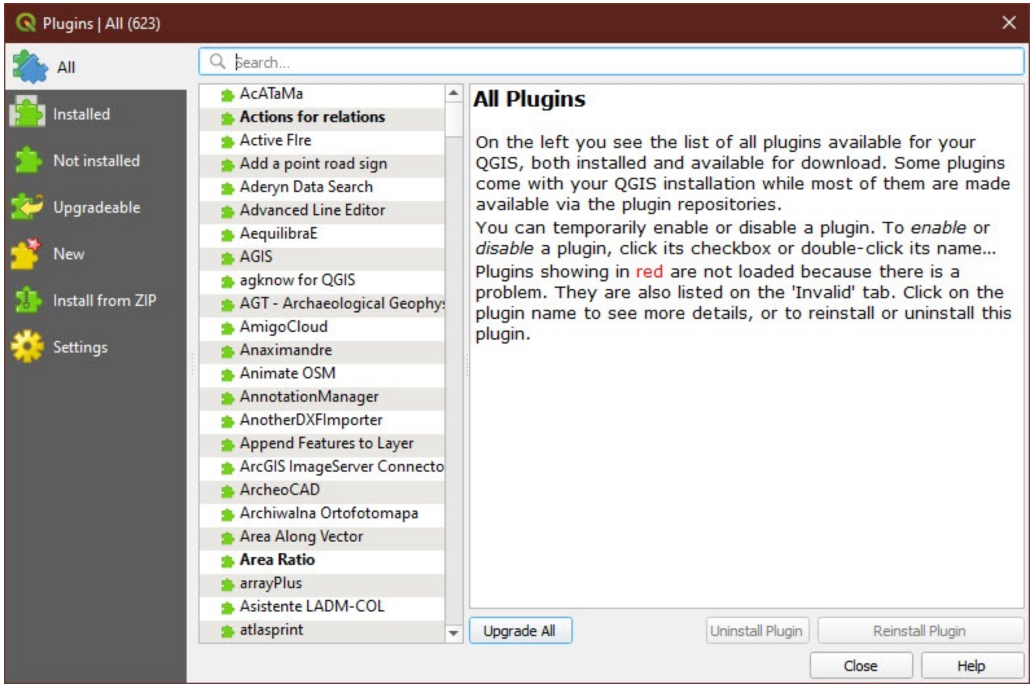
Processing plugin:

a powerful geospatial analysis framework to call native and third-party algorithms from QGIS, such as GDAL, GRASS, SAGA, GRASS, R, etc.



QGIS Plugin Repositories

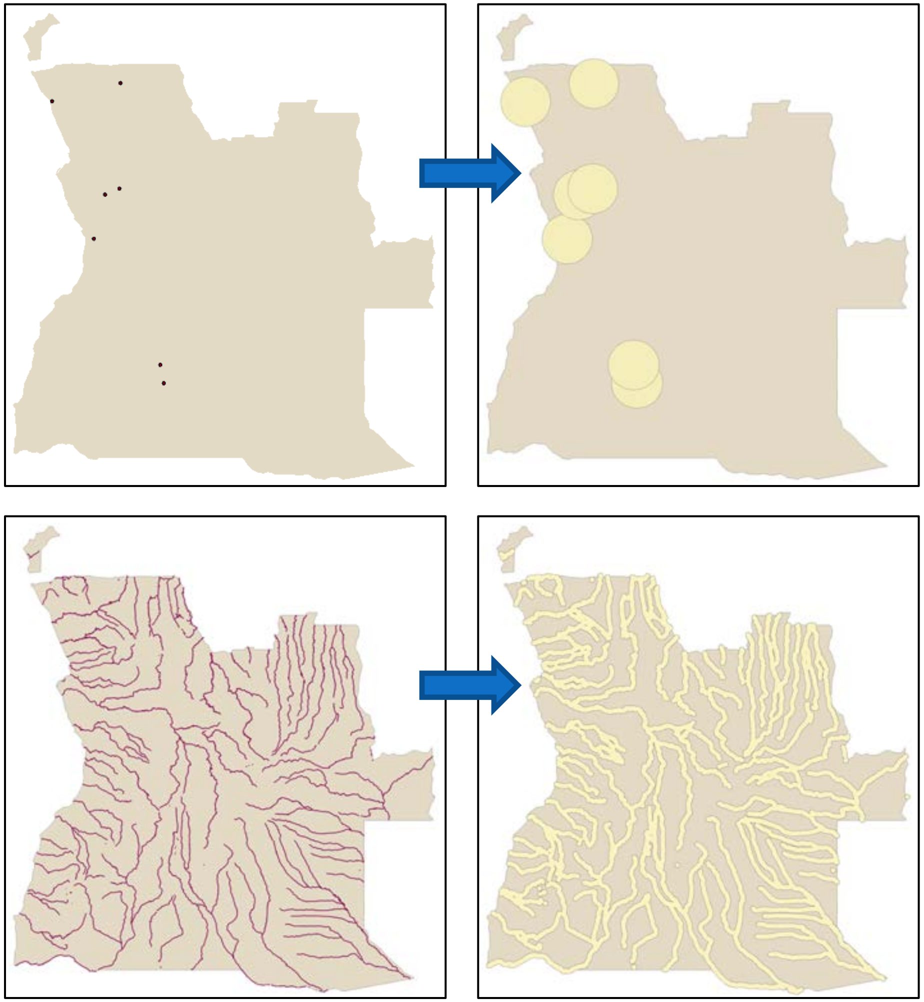
- add useful features to the software
- are written by QGIS developers & other independent users
- available through the Plugins menu



VECTOR ANALYSIS

Buffer

- Creates a polygon around a feature at given distance(s)
- Where, the input feature can be a point, line, or polygon
  - Options to dissolve or create separate features
- Examples:
  - 50 miles around mines
  - 5 miles around rivers



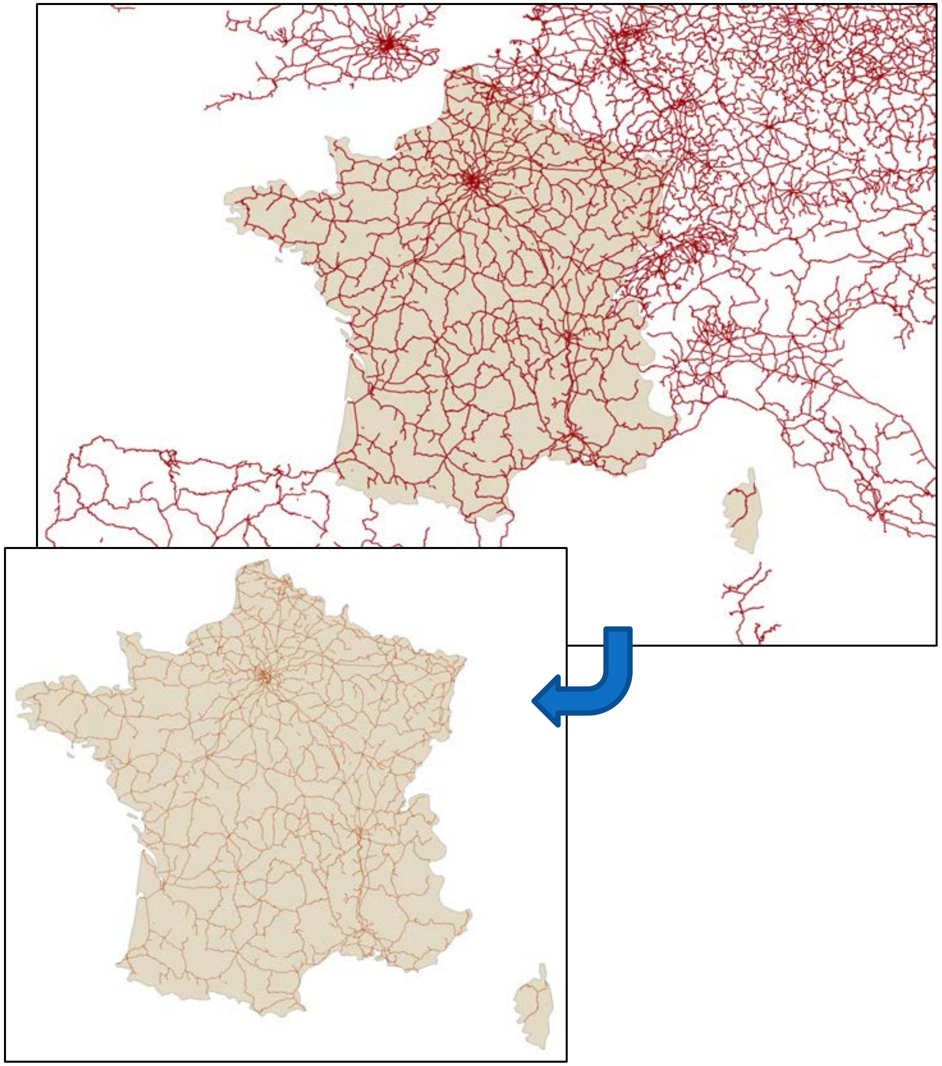
Create and Edit Features

- New shapefiles can be created from scratch
- Features can be edited or created using the editor toolbar in Arc or QGIS
- Example: creating a major road layer (green) for Havana, Cuba based on satellite imagery

Clip (Vectors)

- Use one layer's extent to clip down the features of another layer
  - Input layer can be points, lines, or polygons, but the clip layer must be a polygon

- Example:
  European railroad layer clipped to France layer



Exercise 2: Vector Analysis

Goals

- Learn how to access, interpret, and troubleshoot analysis tools in GIS software

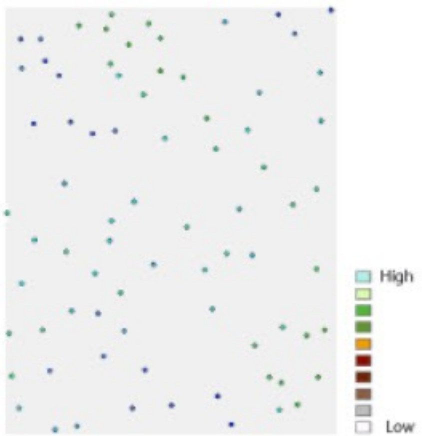
Steps

- You will go back into your breakout room and be guided through the second exercise.

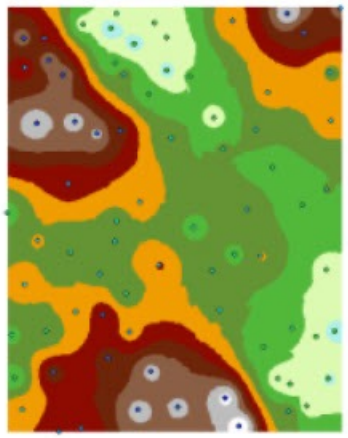
SURFACE ANALYSIS

Interpolation

Create a continuous surface from points.

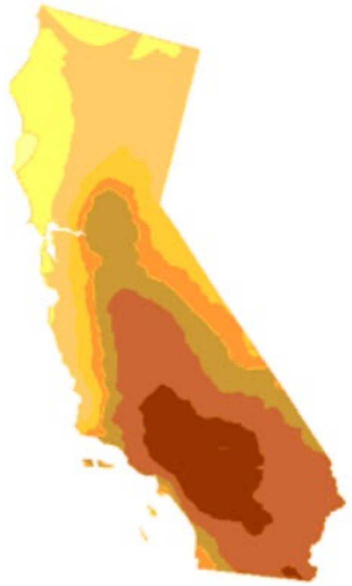


Input elevation point data



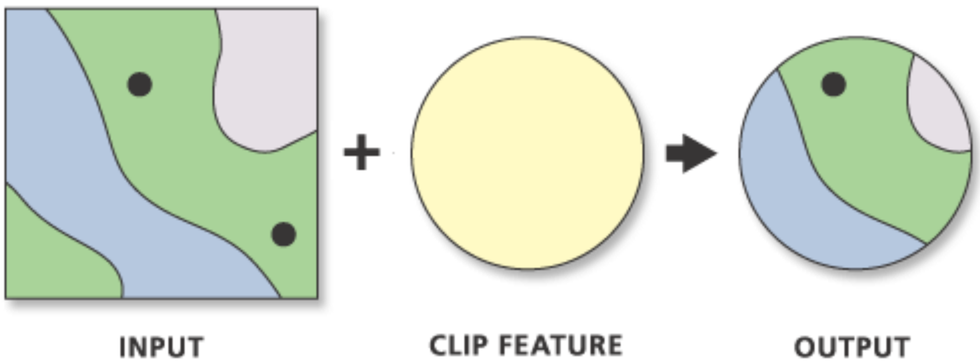
Interpolated elevation surface

Point locations of ozone monitoring stations



Interpolated prediction surface

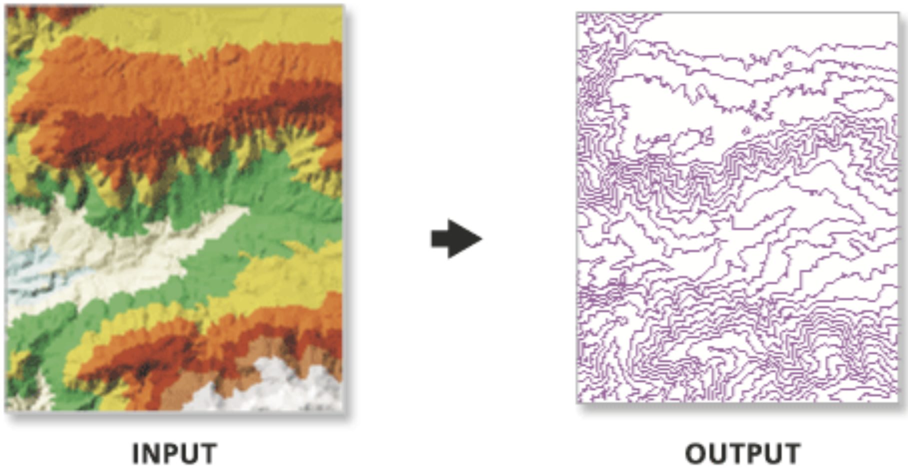
Extract by Mask (Pro)/Clip Raster (QGIS)



- Only cells/pixels within a boundary are retained in output
- Input must be a raster but the clip feature can be anything:
  - points, lines, polygons, or another raster (anything with area)

Contour

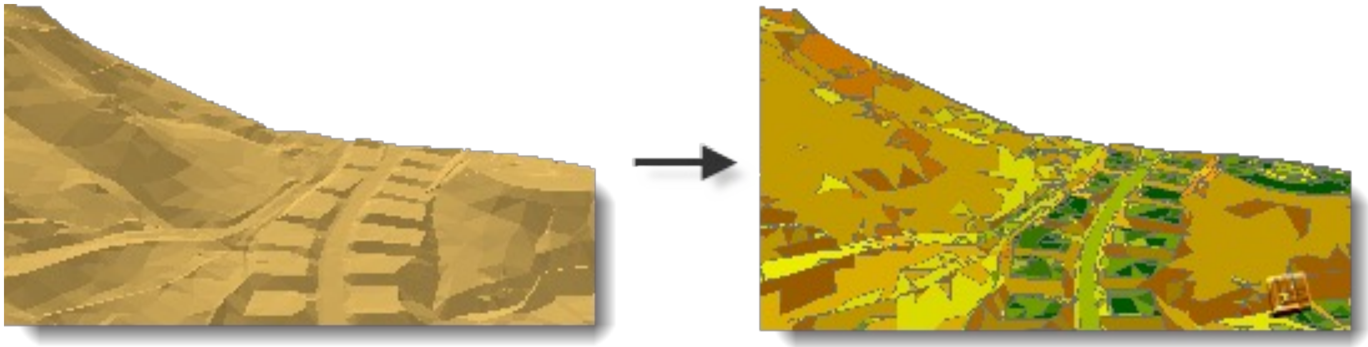
- Creates contour line layer from raster surface.



- Note: they will not extend past the spatial extent of the raster nor in areas with no data

Slope

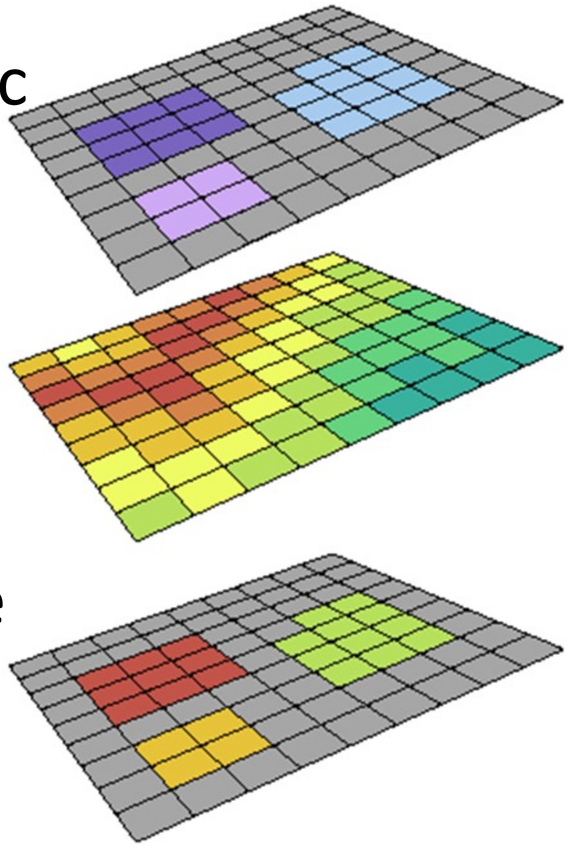
- For each cell, the maximum rate of change in value from that cell to its neighbors is calculated.



Input Surface | Output Slope

- The output slope raster can be calculated in two types of units, degrees or percent (percent rise).

Zonal Statistics (...as Table)



- Zonal Statistics - calculates one statistic (e.g. mean, max, min, stdev, range) from an input raster over a zone/area and produces a new layer.
- Zonal Statistics as Table (Pro)/Zonal Histogram (QGIS) - calculates multiple statistics but produces a table (which can be joined back to geometry, or exported to statistical software)

Surface analysis tools: also are used to…

- Analyze Patterns
- Analyze Terrain
- Generalize
- Conduct hydrological analysis
- Manage Data
- Summarize Data
- Use Proximity

Exercise 3: Raster tools

Goals

- Learn how to access raster tools

Steps

- You will go back into your breakout room and be guided through the third exercise.

SPATIAL STATISTICS

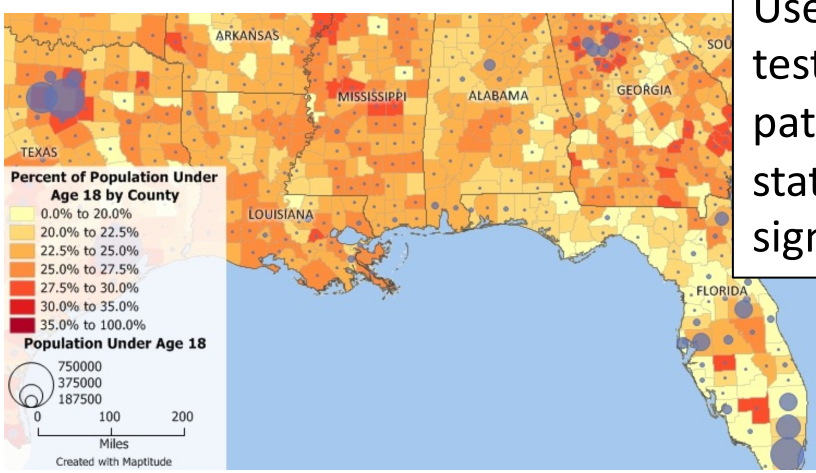
What are spatial statistics?

- methods for analyzing spatial distributions, patterns, processes, and relationships

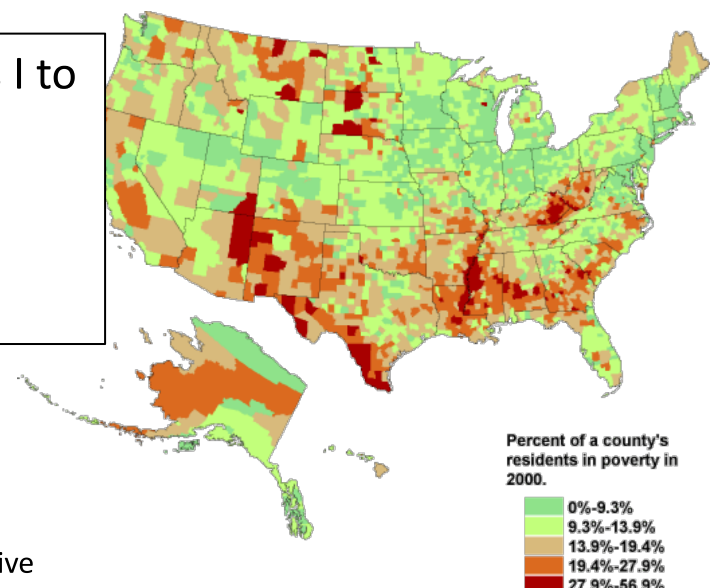
- they incorporate space (proximity, area, connectivity, and/or other spatial relationships) directly into their mathematics

Spatial autocorrelation (Moran's I)

- Measures the patterns of **attribute values** associated with features (ex. median home value, percent female, etc.).
- **Compares the value** of the feature **to that of its neighbors** and the entire study area.
- Indicates clusters of high or low values (positive I value) or outliers (negative I value).

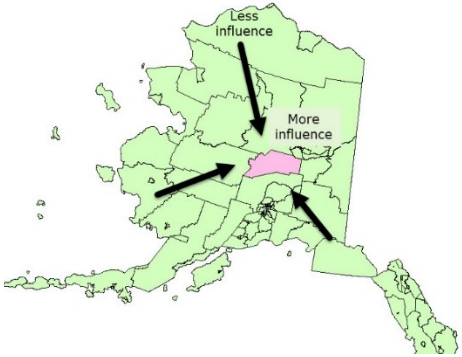


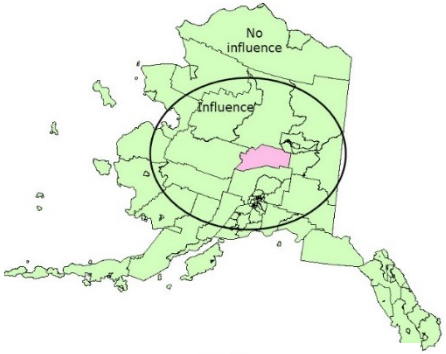
Use Moran's I to test visual patterns for statistical significance.

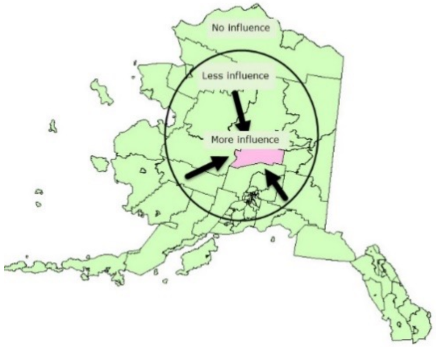


Neighbors: Distance Models

- **Inverse distance:** all features influence all other features, but the closer something is, the more influence it has
- **Distance band:** features outside a specified distance do not influence the features within the area
- **Zone of indifference:** combines inverse distance and distance band

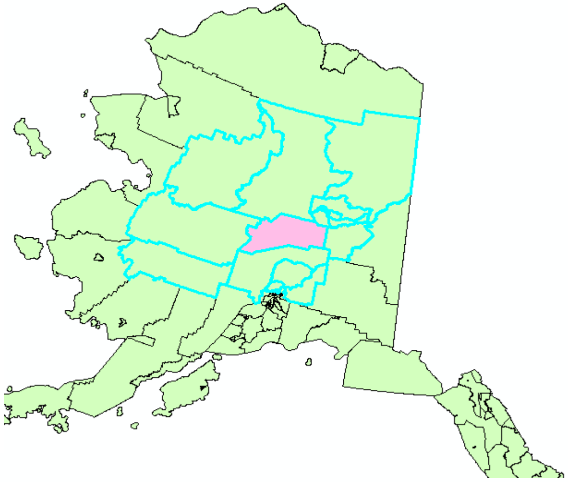


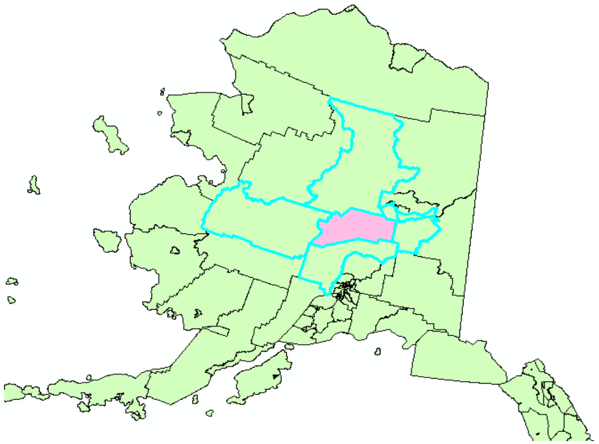




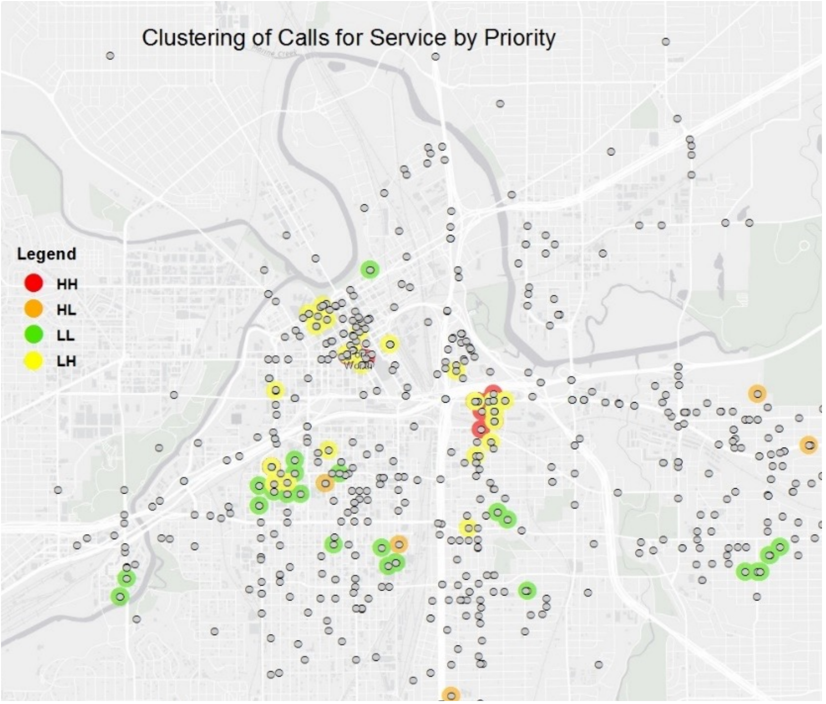
Neighbors: Adjacency Models

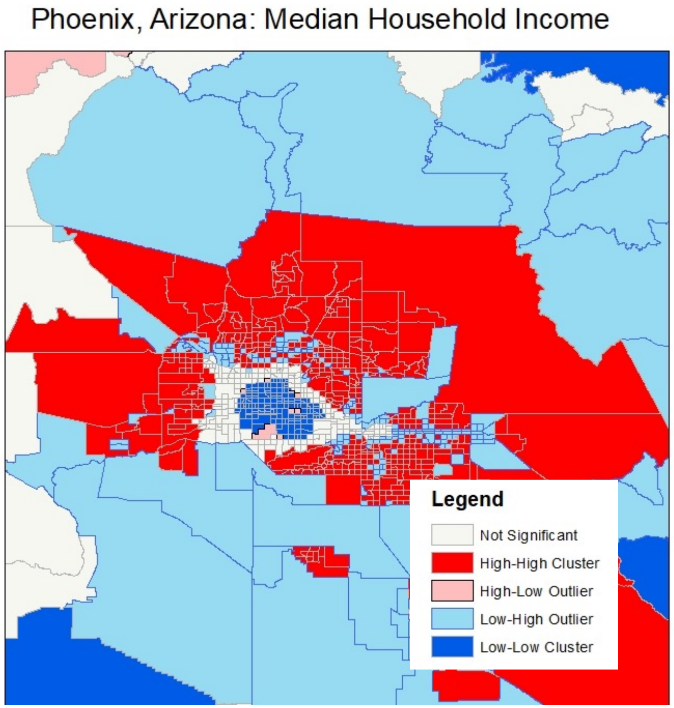
- **K Nearest Neighbors:** a specified number of neighboring features are included in calculations
- **Polygon Contiguity:** polygons that share an edge or node influence each other
- **Spatial weights:** specified by user (ex. Travel times or distances)





Spatial autocorrelation (Moran's I)





Other spatial statistics tools

- Analyzing patterns
  - Nearest neighbor, Ripley's K
- Geographic distributions
  - mean, median, directional mean
- Regression
  - Geographic, Ordinary Least Squares (OLS)

Exercise 4: Spatial Statistics

Goals

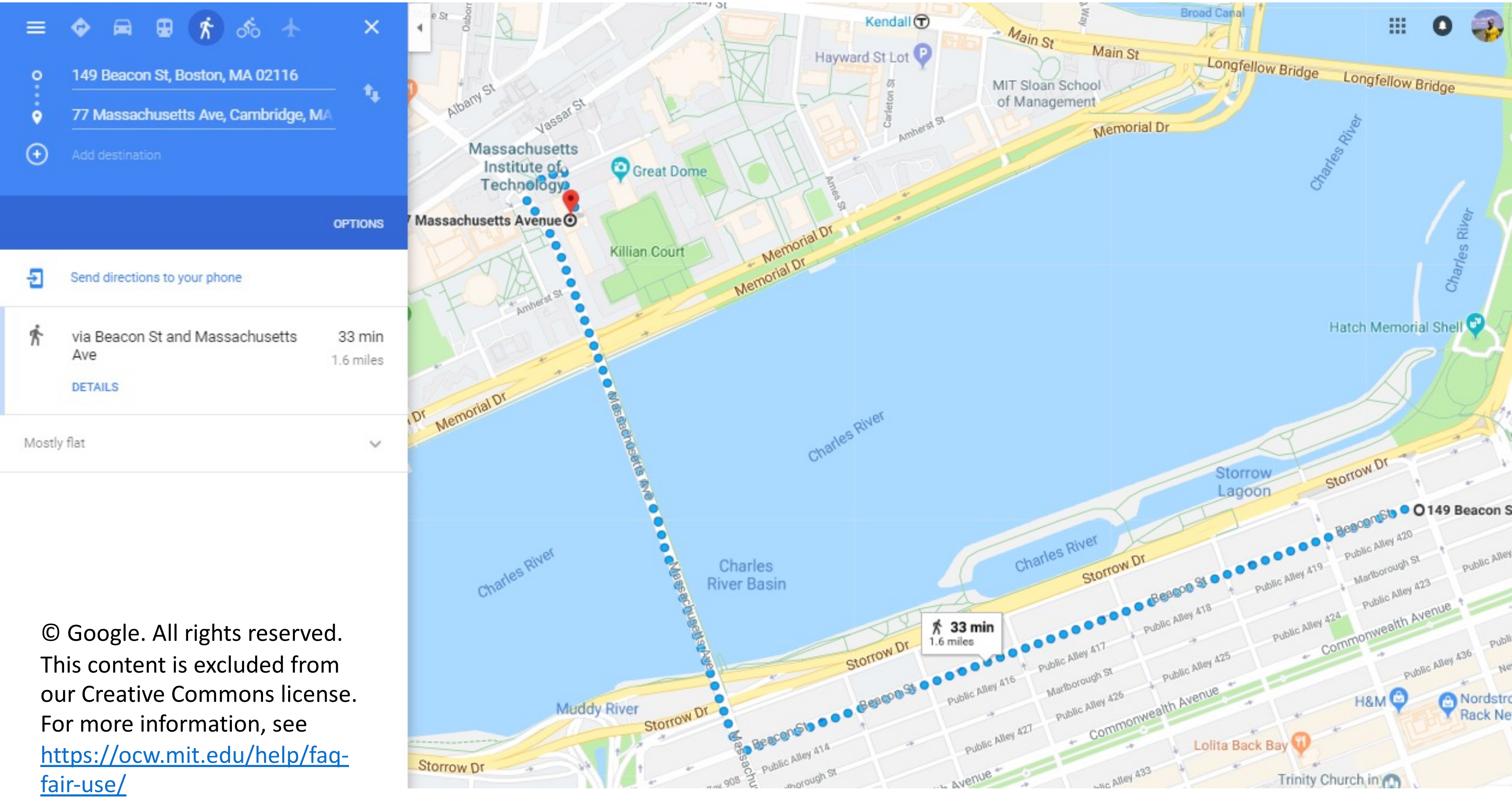
- Learn how to access specialized analysis tools
- Understand the results of a basic spatial autocorrelation.

Steps

- You will go back into your breakout room and be guided through the fourth exercise.

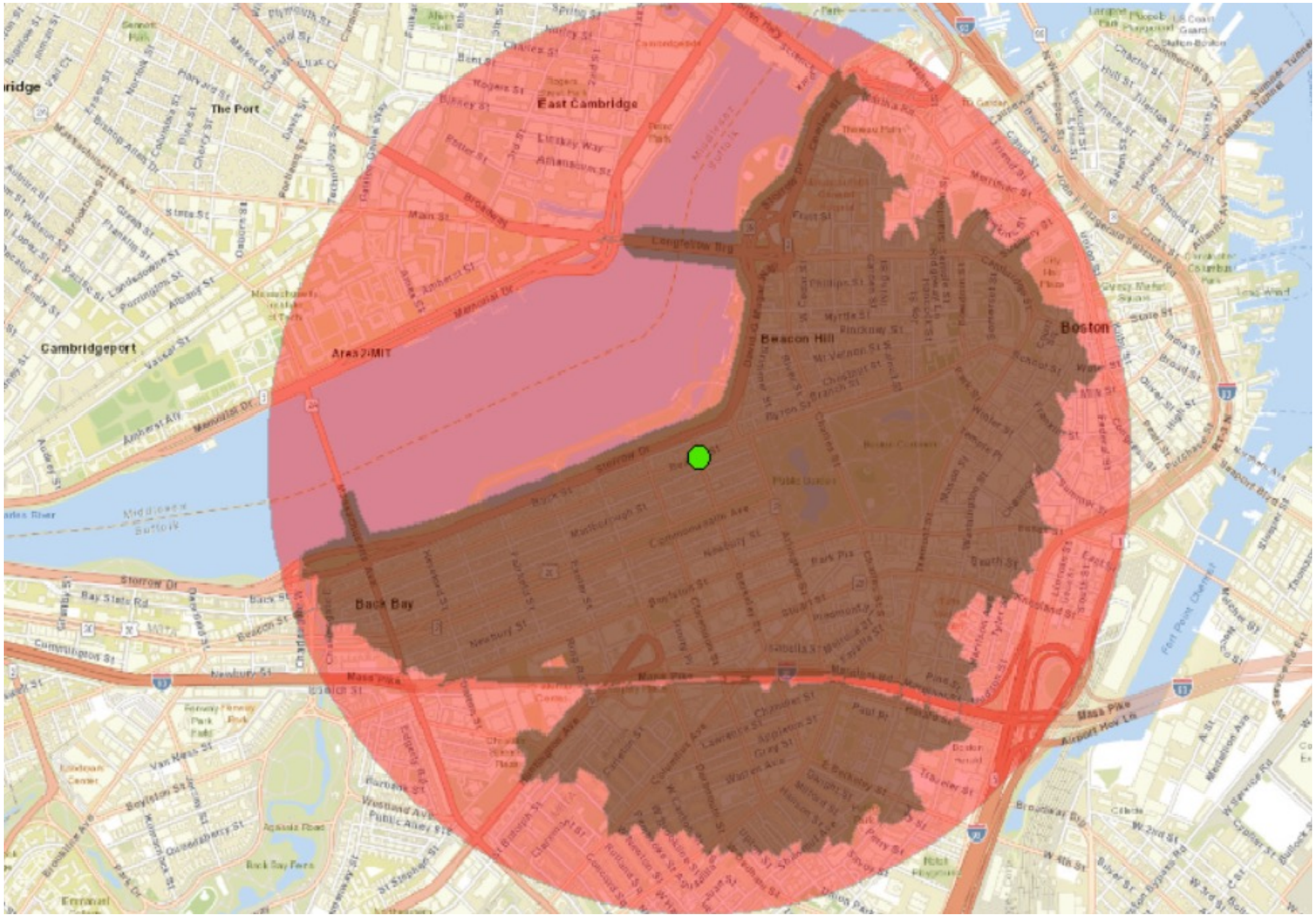
DISTANCE & NETWORK ANALYSIS

Distance in a GIS



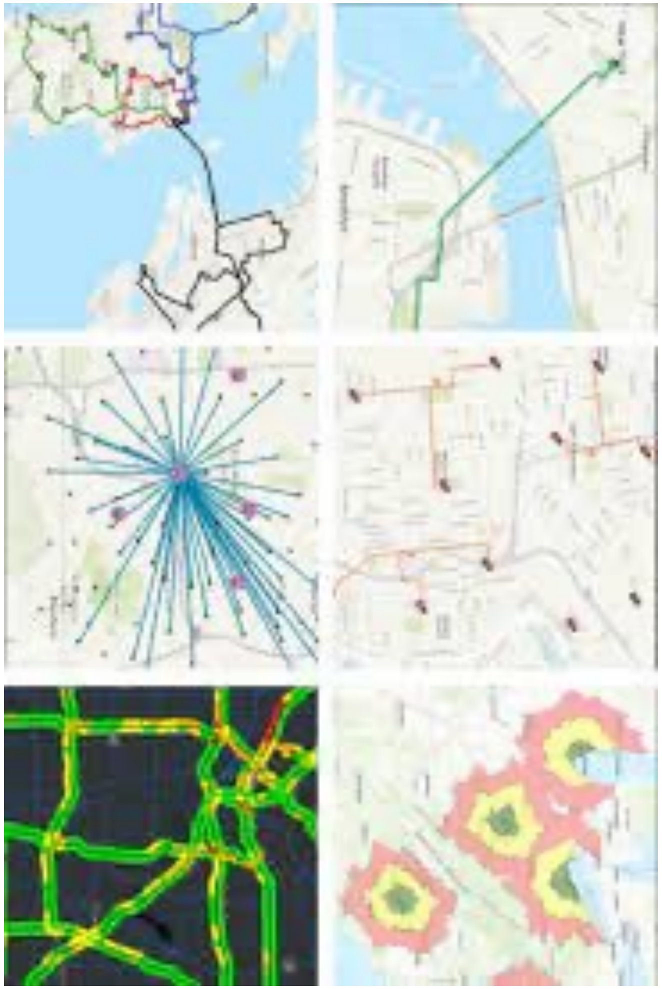
Distance functions in GIS

Without regard to any network, **over the surface of the earth** vs **on a road** network



Network Analysis Tools

- Routing
- Service Areas
- Closest facility
- OD Cost Matrix
- Vehicle Routing Problem
- Location-Allocation
- (Only for ArcGIS Products)



TAKE-HOME EXERCISE

Take-home Exercise overview

- Continuing with the data from GIS Level 1, explore where you may build a mixed use facility in Jersey City.
- This exercise will take into account the following factors:
  - Clustering of unemployment
  - Distance to transportation
  - Terrain