In-Class Exercise: Global Map Projections

Purpose

- Use Tissot's Indicatrix and Graticule to visualize area, distance and shape on projections
- Interpret area, distance, and shape properties of common global map projections

Outcomes

- Table interpreting map properties of common global map projections.

Data

- The world countries and graticule data for this activity was created by the open source data project for cartography, *Natural Earth* https://www.naturalearthdata.com/

Procedure

- Gather around printed global maps in small groups to interpret the global map properties and fill out the following table's "equal area", "equidistant", "conformal", and "azimuthal" columns indicating which properties are accurate, or not, for each projection.
- **Tissot's indicatrix** is composed of equally-sized circles spaced out around the globe surface. Examine these circles on the maps
  - If the "circles" are distorted into other shapes, then shape is not preserved
  - If the length of a line passing through the "circles" is not constant in a given direction on the map, then distance is not preserved.
  - If the "circles" are different sizes, then area is not preserved.
- The **graticule** is the grid of lines of latitude and longitude.
  - Lines of latitude, as "parallel" lines, should always remain the same distance apart from one another
  - Lines of longitude normally converge at the poles.
  - If local shape and direction are preserved, then lines of latitude and longitude intersect orthogonally
- Note that no map projection can preserve distance everywhere, in all directions. If distance is accurate, be specific about where, and in what directions.
- Note that the only map property that may be accurately combined with any other is azimuthal (direction)
- Fill out the final row "possible use cases…" for common and appropriate uses of this projection.

Projection	WGS 1984 GCS / Plate Carrée EPSG: 4326 or 32662	World Mercator EPSG: 3395	Cylindrical Equal Area: 54034	Azimuthal Equidistant: 54032 (also 102016 and 102019)	Equidistant Conic: 54027	Mollweide: 54009	Robinson: 54030
Equal Area	No, it does not even use linear units!						
Equidistant	No, it does not even use linear units!						
Conformal	No, shapes are stretched E/W at poles						
Azimuthal	Only directly N/S or E/W						
Possible use cases …							

Lab: Map Projections for Conservation Areas in the U.S.

Which map projections are best for analysis of different conservation areas?
Which conservation areas are most compact in shape, and which ones have the most inaccessible interior habitat?

Purpose

- Understand the impact of map projections on spatial analysis
- Calculate and visualize map projection error (or any type of error!)
- Apply principles of conservation biogeography / landscape ecology in GIS

Outcomes

- Calculations of the percentage error in common map projections for the Lower 48 states
- Estimates of compactness and (in)accessibility within conservation interiors
- Selection of the best map projection for five different conservation regions

Data

- Reference data layers are from Natural Earth, a free and open source collection of geographic data for cartographers. See http://www.naturalearthdata.com/

- **Title**: `map_projection_givens` geopackage| `protected_areas` layer
- **Responsible Party**: Data compiled by Professor Holler
- **Spatial Representation Type**: Vector polygons
- **Spatial Coverage**: Continental United States
- **Spatial Resolution**: Unknown
- **Spatial Reference System**: EPSG 4326: World Geodetic System 1984 geographic coordinate system
- **Temporal Coverage**: unknown / out of date
- **Lineage**: Compiled from ProtectedPlanet https://www.protectedplanet.net/ and the United States' Wilderness Areas: https://www.wilderness.net/GIS. Each polygon has been merged with any adjacent polygons and assigned the name of the largest conservation area. The resulting dataset is known to contain one or more geometry errors.
- **Distribution**: Available free from https://geog261.github.io course website in geopackage format
- **Constraints**: The data is out-of-date, and not permitted for redistribution beyond the educational purposes for a GIS course.
- **Attributes**:
  - **Name**: NAME
  - **Description**: Name of the largest conservation area contributing to the polygon feature
  - **Data type**: text string
  - **Accuracy**: unknown and definitely variable! Many names are ambiguous or missing.
  - **Domain**: nominal identifiers
  - **Missing data**: *NULL* indicates a missing name for 667 features

Procedure I: Central Falls Tutorial

First, learn how to implement new techniques of Reproject Layer, Pole of Inaccessibility, and calculating compactness using the Central Falls tutorials.

1. **Copy** your Central Falls project to the Documents folder.
2. **Video:** Reproject Layer
3. **Video:** Pole of Inaccessibility
4. **Video:** Compactness
5. **Save and Back up** Central Falls project to the network Drive.

Procedure II: Projections and Conservation Areas

Second, calculate some metrics for conservation areas (area, perimeter, compactness and pole of inaccessibility) and visualize error in calculations of the first three.

1. **Open** the conservation_areas.qgz project in QGIS
2. **Video**: Geodesic Calculations
3. **Workflow without video**: Calculating metrics for conservation areas using the workflow described and diagrammed below.
4. **Video**: Visualizing Error

Workflow Diagram

1. Given the `protected_areas` dataset, calculate the area, perimeter, and compactness of each protected area using *geodesic* calculations.
2. Change the projected coordinate system of `protected_areas` to `ESRI:102004 USA_Contiguous_Lambert_Conformal_Conic`. Then, recalculate the area, perimeter, and compactness of each protected area using planimetric calculations.
   Compactness is: `(400 * pi() * A) / P^2` where A is Area and P is Perimeter
3. Calculate the percentage error for each metric (area, perimeter, compactness) using the general formula:
   `(Geodesic Calculation – Planimetric Calculation) / Geodesic Calculation * 100`
4. Find the most inaccessible interior point of each conservation area and the distance from that point to the boundary.

I suggest you use consistent field names to organize calculations:

`geo_area`: geodesic area `geo_perim`: geodesic perimeter `geo_comp`: geodesic compactness	`pla_area`: planimetric area `pla_perim`: planimetric area `pla_comp`: planimetric compactness percent error	`area_err`: planimetric area percent error `perim_err`: planimetric area percent error `comp_err`: planimetric compactness percent error

Draw Workflow Here

Check and Interpret Results

statistic	geodesic			conformal conic planimetric			percent error		
	area	perimeter	compact	area	perimeter	compact	area	perimeter	compact
Mean	1.75E+08	75952	29.861	1.75E+08	75867	29.861	0.243	0.123	0.000
Minimum	9.77E+06	13044	0.812	1.00E+07	13125	0.812	-4.392	-2.118	-0.106
Maximum	2.42E+10	3904560	88.959	2.41E+10	3897480	88.959	1.089	0.546	0.080

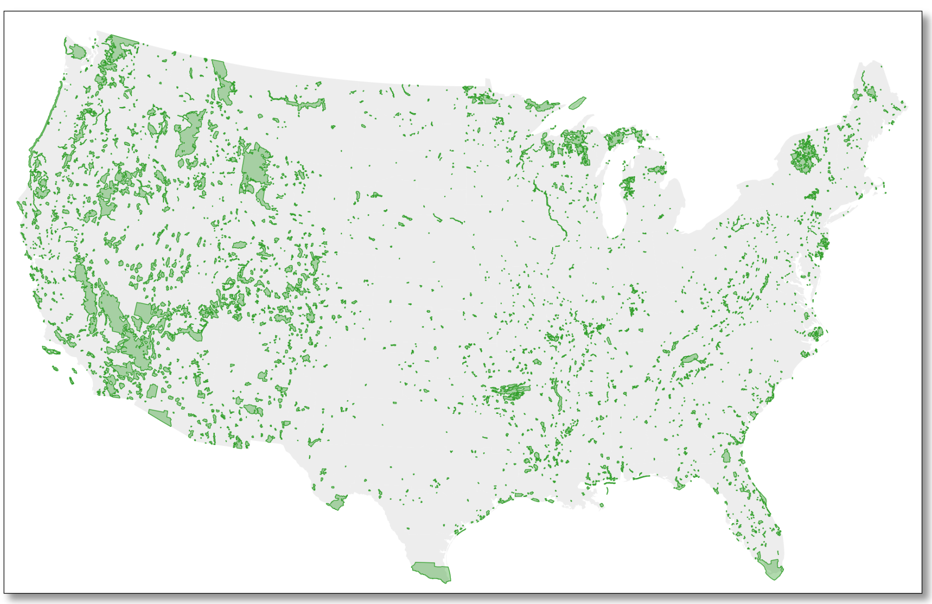
statistic	Distance to Pole
Mean	2556.31
Minimum	368.567
Maximum	44625.5

1. What is the most compact conservation area? What is the least compact conservation area?

2. Which conservation area has the most inaccessible point?

3. Compare the amount of error in the three measurements (area, perimeter, compactness) for the conformal conic projection. Which of the three has the most error, and which has the least? Why?

4. Please draw where you think the standard line(s) are for the `Lambert Conformal Conic` projection. How did you know where to draw the lines?



Procedure III: Choosing the Best Map Projection

Third, Imagine that you are applying for a GIS internship at an environmental non-governmental organization. As part of the application process, you are tasked with making a series of maps of selected conservation areas. Use the guide to choosing the right projection discussed in lecture. What do you think the best map projection for each of the following areas would be?

- Use the `state_plane` and `utm` layers to the map for reference. These layers are indices for the geographic regions in which each State Plane coordinate system or each UTM Zone coordinate system is most appropriate.
- See the **Choosing the Best Projection** video for technical guidance
- The relevant conservation areas are highlighted in the **conservation_foci** data layer.
- Remember the final topic from lecture to guide your decisions…
- Please write down your best projection idea(s) for each study area.

1. **Everglades** (Florida)

2. **Ouachita** (Arkansas)

3. **High Peaks** (New York)

4. Conservation of the Rio Grande River on the border between Texas and Mexico from **Big Bend** to **Lower Rio Grande Valley** (see the `rio_grande` layer)

5. Conservation of a three-state region in the West broadly from **Olympic** in Washington to **Kings Canyon** in California: see the `cascadia_sierra_nevada` layer).

Procedure IV

Finally, see learn how to visualize global map projections and fix layers with missing coordinate reference systems using tutorial videos.

1. **Download** the Conservation_Project.zip file from the course site and **unzip** the contents to your **Documents** folder
2. **Open** the global_map_projections.qgz project in QGIS
3. **Video:** Undefined CRS
4. **Video:** Managing Coordinate Reference Systems
5. **Save** the QGIS project, **close** QGIS, and **back up** your work to the network

Am I Done?

Please check all of your answers with an instructor

- ❑ Global projections activity
- ❑ Conservation area results and questions
- ❑ Choosing the best map projection questions

Projections: Lessons Learned

Key Take-aways:	1. Two-dimensional maps always distort distance, shape, direction, or area. 2. Map projections customized to a small extent (e.g. state plane zones) are accurate enough for analysis of any map property. 3. Map projections for larger extents necessarily compromise some map properties. 4. Geodesic/ellipsoidal functions are the most accurate, but they require more complex calculations and are not available for all GIS software or software algorithms.
Advice for working with projections	Although you've only seen some of the tools mentioned below so far, the general concepts should already make sense: 1. Many GIS functions are sensitive to the accuracy of distance or area in the map projection, and these include ❑ Pole of Inaccessibility (for calculation of distance to the perimeter) ❑ Field Calculator formulas with area() perimeter() or length() ❑ Buffer ❑ Direction and Distance 2. Other GIS functions are sensitive to the accuracy of shapes on the map projection, and these include ❑ Pole of Inaccessibility (for location of the point) ❑ Calculations of compactness ❑ Centroids 3. Good practice is to Reproject all of the spatial data layers used for analysis into the **same map projection**. This is particularly important for overlay functions (Intersection, Union, Clip, and Difference) for Spatial Join, and for Select by Location (if the selection must be very precise).
Check your Knowledge	When would you use each of the following features in QGIS? 1. Reproject Layer tool 2. Change the QGIS Project CRS 3. Set the CRS of a Layer and Export it