

INTEGRATING DATA WITH MAPS

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Remember the Geometry We Accessed for NY

```
...  
geom_cd =  
ny_cd.at[0, 'geometry']  
print(geom_cd)
```

← at accesses a single DataFrame element by label, so this statement accesses the geometry of the first row (Congressional District # 1)

```
POLYGON ((742169.5257000001 4532898.369100001, 736334.2504000003 4529
```

← The polygon is represented as a series of coordinate pairs where the coordinates are measured in longitude/latitude

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Remember the NY-1 File

```
...
ny_cd1 = gpd.read_file('NYS_Congressional_District_01.json')
print(ny_cd1)

print("The crs of this GeoJSON is ")
print(ny_cd1.crs)
```

```

OBJECTID  District  ... State                geometry
0         1         1  ...   DC  MULTIPOLYGON (((-72.80536 40.75559, -72.80575 ...

[1 rows x 13 columns]
The crs of this GeoJSON is
EPSG:4326
```

ESPG:4326 is the latitude/longitude coordinate system

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Are We on Track?

- Can you locate (-72.80536, 40.75559) in Google Maps?
- Why the minus sign?
- Is the GeoJSON using lat/long or long/lat?
- What coordinates are given by Google Maps?



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Geographic Coordinate Systems (GCS)

- “Spherical or ellipsoidal coordinate systems for measuring and communicating positions directly on the Earth as latitude and longitude” (Wikipedia)
- Measurements are angles (not like a cartesian coordinate system)
- Latitude shown as Φ (phi) and longitude shown as λ (lambda)

But we're not used to measuring distances in angles

Compare these distances

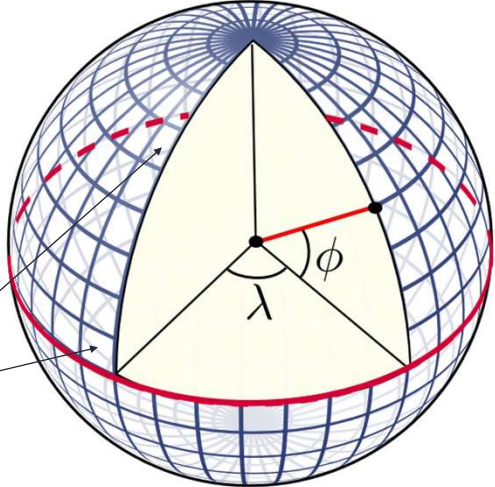


Image: Wikipedia

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Latitude and Longitude

- Latitude – lines are horizontal and represent the distance north or south from the equator
- Longitude – (also called meridians) run vertically pole to pole and measure distance east or west from Greenwich (England)
- Measured in degrees, minutes, and seconds
- Formats
 - Degrees, Minutes, Seconds: 40° 56'05.3"N 73°17'47.3"W
 - Degrees and decimal minutes:
 - Decimal degrees: 40.934797, -73.296459

Enter this in Google Maps search, and see which region it shows

Go to Google Maps and lookup your current latitude and longitude
Also look for the 0 position of latitude and longitude

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Latitude / Longitude Example



A Google Maps search for this lat/long results in this format

Notice that the search latitude is -72.805360, which is equivalent to 72° 48' 19.3" W

Notice that the order of lat and long is reversed

```
MULTIPOLYGON (((-72.80536 40.75559, -72.80575 ... geometry
```

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Coordinate Reference Systems

- Cartesian coordinate systems provide advantages over lat/long
 - Meaningful for smaller regions
 - Represent actual ground distances and intuitive sense of scale and distance
- Examples
 - WGS84 – latitude longitude projection ("EPSG:4326")
 - UTM Zones (North) ("EPSG:32633")
 - UTM Zones (South) ("EPSG:32733")

A lat/long plot of North America shows an elongation of areas in the north

The US is too big to have a national coordinate system

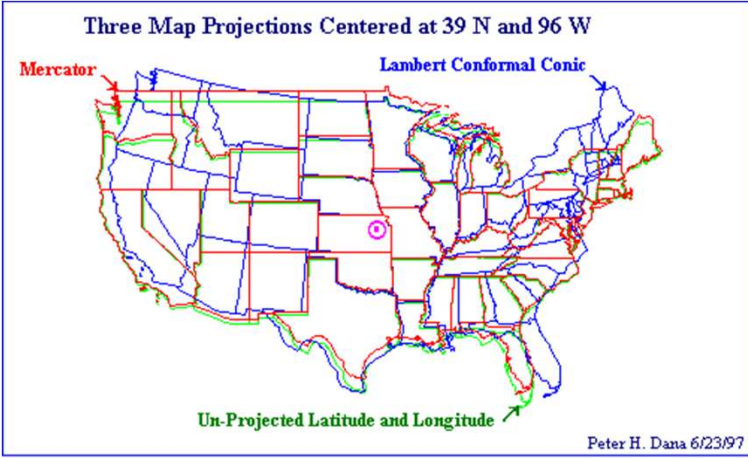
Google Maps

en.wikipedia.org/wiki/List_of_national_coordinate_reference_systems

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Coordinate Systems



Three Map Projections Centered at 39 N and 96 W

Mercator Lambert Conformal Conic

Un-Projected Latitude and Longitude

Peter H. Dana 6/23/97

Different projections of spherical coordinates to 2D coordinates show shapes differently

When map data is combined, the CRS of each map should be the same

<https://www.acsu.buffalo.edu/~dbertuca/maps/cat/map-projections.html>

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Shapely Geometry

- Geometry is represented in shapely
- Examples
 - Point – a single x,y value
 - Polygon – an area enclosed by a linear ring
 - MultiPolygon – collection of one or more Polygons

Shapely does not assume a coordinate system; points are just simple x,y coordinates

```
from shapely.geometry import Point
my_loc2 = Point(-73.04658, 40.95258)
print(my_loc2)
```

↓

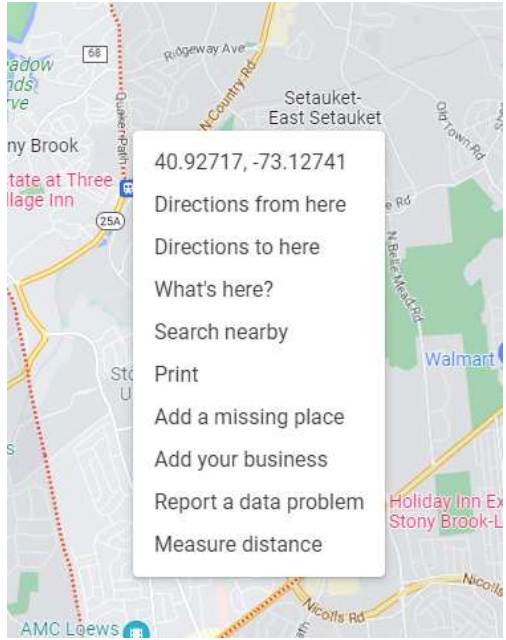
POINT (-73.046580000000001 40.95258)

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Are We on Track?

- Use Google Maps to find the geolocation of some location in your favorite state
- Use Google Maps to find the 0 longitude geolocation



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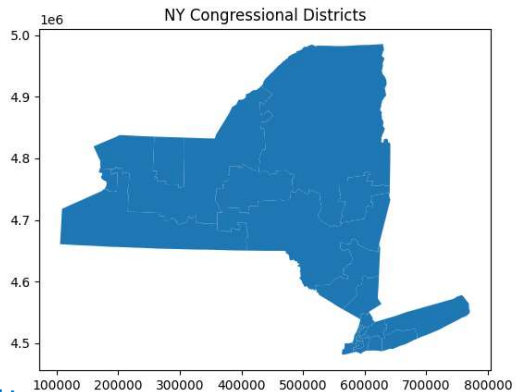
Example ...

- We read the 2024 NY Congressional District shapefile and determine which coordinate system it uses

```

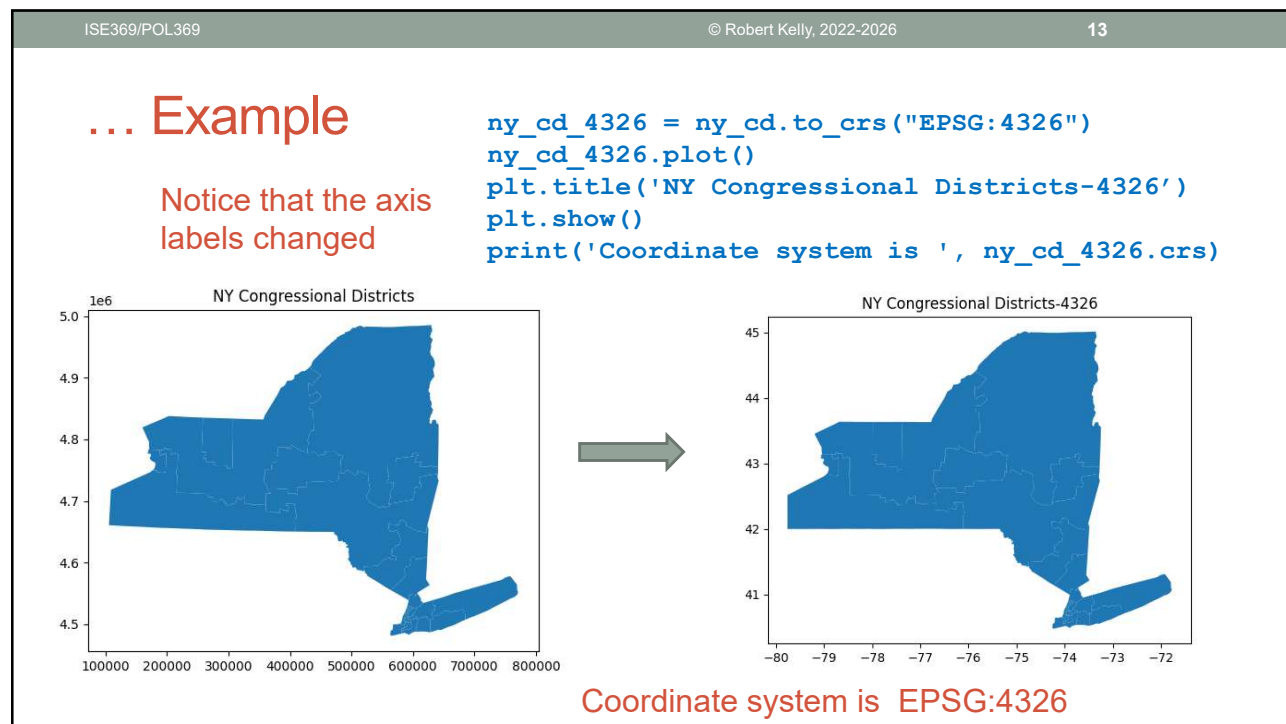
os.chdir('G:\\My Drive\\Courses\\ISE369\\Data'
+ '\\GeoDataDisplayLesson\\ny_cong_adopted_2024'
+ '\\CON24_shapefile_Feb_28_2024')
ny_cd = gpd.read_file('con24.shp')
ny_cd.plot()
plt.title('NY Congressional Districts')
plt.show()
print(Coordinate system is ', ny_cd.crs)
```

Coordinate system is EPSG:26918



ESPG: 26918 is a high accuracy crs used in eastern US

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DataFrame Information

- `df.info()` - display number of rows, columns, etc.
- `len(df)` - get the number of rows
- `len(df.columns)` - get the number of columns
- `df.shape` - Get the number of rows and columns
- `df.size` - Get the number of elements:

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DataFrame Info Method

```
print(ny_cd.info())
```

```
<class 'geopandas.geodataframe.GeoDataFrame'>
RangeIndex: 26 entries, 0 to 25
Data columns (total 3 columns):
#   Column   Non-Null Count  Dtype
---  ---
0  OBJECTID  26 non-null    int64
1  DISTRICT  26 non-null    int32
2  geometry  26 non-null    geometry
dtypes: geometry(1), int32(1), int64(1)
memory usage: 652.0 bytes
None
```

← No return from method

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Iterate Over a DataFrame

```
...
for i in range(len(ny_cd)) :
    print(i, 'Congressional District ', ny_cd.loc[i, "DISTRICT"])
```

Python range function returns a sequence of numbers starting at 0 (default) and ending before the specified number

```
0 Congressional District 1
1 Congressional District 2
2 Congressional District 3
3 Congressional District 4
4 Congressional District 5
5 Congressional District 6
6 Congressional District 7
7 Congressional District 8
```

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Are We on Track?

- Let's use the geopandas DataFrame to calculate which congressional district of some location in your favorite state
- You will need to
 - Determine the geolocation of that location
 - Test to see which congressional district contains that geolocation
 - Display the name of that congressional district
 - Use lat/long for all coordinates
 - Hint: Use the Shapely method - *object.within(other)* - returns True if the object's boundary and interior intersect

CRS of ny_cd is epsg:26918

New NY coordinate system is epsg:4326

My CD is 1

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Were We On Track?

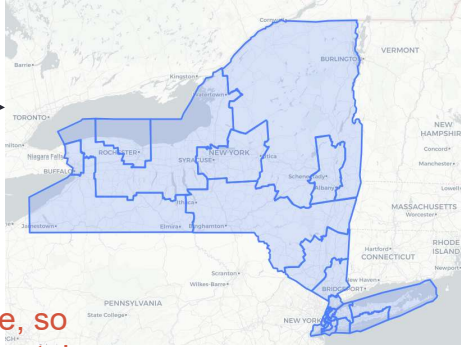
```
...
print("CRS of ny_cd is ", ny_cd.crs)
ny_cd_google = ny_cd.to_crs(epsg=4326)
print('New NY coordinate system is ', ny_cd_google.crs)
my_loc2=Point(-73.04658, 40.95258)
for i in range(len(ny_cd)) :
    geom_cd=ny_cd_google.at[i,'geometry']
    if (my_loc2.within(geom_cd)):
        print('My CD is ', ny_cd.loc[i, "DISTRICT"])
```

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Let's Combine a Map With the NY District Border

- First, we extract the shapefile that defines the NY congressional district borders
- Then we combine the borders with map of NY state

Shapefile → Converter → Geo.Json → Python → HTML → Browser → 

Folium essentially translates calls to the Python API into calls to the Leaflet API

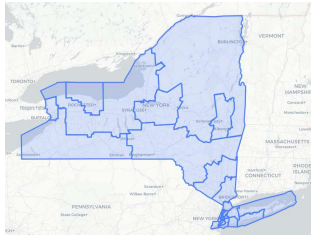
There's a lot going on here, so let's look at each part separately

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Let's Combine a Map With the NY District Border

- First, we extract the shapefile that defines the NY congressional district borders
- Then we combine the borders with map of NY state

Shapefile → Converter → Geo.Json → Python → HTML → Browser → 

Basemap

This approach requires district boundary data in GeoJSON format

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Convert to GeoJSON

- Many apps require a GeoJSON (not a shapefile)
- Generating a GeoJSON is simple
- Example creates a GeoJSON file named ny_geo

```
{
  "type": "FeatureCollection",
  "crs": {
    "type": "name",
    "properties": {
      "name": "urn:ogc:def:crs:EPSG::26918"
    }
  },
  "features": [
    {
      "type": "Feature",
      "properties": {
        "OBJECTID": 1,
        "Shape_Leng": 398240.168961,
        "Shape_Area": 4747142907.56,
        "DISTRICT": 1
      },
      "geometry": {
        "type": "Polygon",
        "coordinates": [
          [
            [
              ...
            ]
          ]
        ]
      }
    }
  ]
}
```

```
ny_cd = gpd.read_file('ny_cong_adopted_2022.zip')
ny_cd.to_file('ny_geo', driver='GeoJSON')
```

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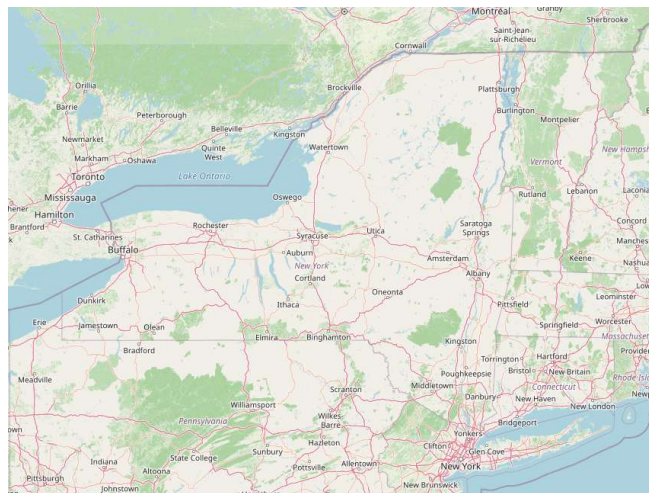
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Map Generation

- We generate a map of the NY area with just one call to folium
- The statement constructs a Map object centered at the location specified and zoomed in to the level specified



```
Import folium
world_ny = folium.Map(location=(42.9525, -76.01667), zoom_start=7)
world_ny.save("world_ny.html")
```

Browser display
of world_ny.html

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Are We on Track?

- Add folium to your project
- Build and save a folium map of your favorite state
- Open the saved file in your browser
- How do you find the lat, long of your favorite state?
- Pan and zoom (Do you notice the detail changing?)
- What details become visible as you zoom?

```
import folium
world_ny = folium.Map(location=(42.9525, -76.01667), zoom_start=7)
world_ny.save("world_ny.html")
```

Code for NY State

The type of world_ny is a folium Map object

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Map Tiles

- Web mapping systems (e.g., Google Maps, Leaflet) are based on storing map tiles
- Track: Interact with the image at <https://www.maptiler.com/google-maps-coordinates-tile-bounds-projection/#5/19.75/26.27>
- As you pan and zoom in your favorite state, your browser loads and displays different tiles

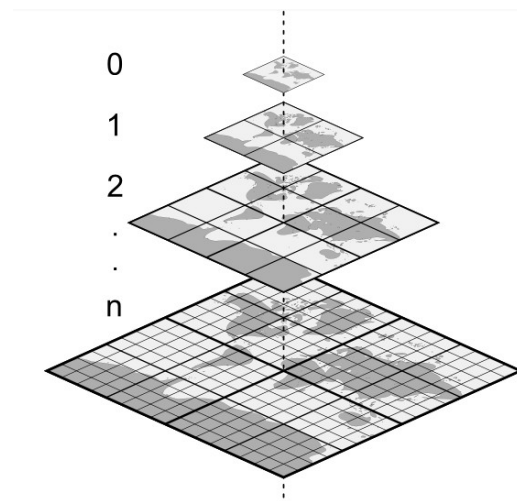


Image: developers.planet.com

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Generated HTML

```
</body>
<script>
```

- If you view source in your browser, you can see the html generated by folium
- Notice that some of the parameters you passed to folium are used to set Leaflet attributes in the HTML
- Notice the scripts that refer to various JavaScript libraries

```
var map_b78b258c428c705415708a52f83462e,
    "map_b78b258c428c705415708a52f83462e"
    {
      center: [42.9525, -76.01667],
      crs: L.CRS.EPSG3857,
      zoom: 7,
      zoomControl: true,
      preferCanvas: false,
    }
  );

var tile_layer_f6ba185d06dfbcf283f4c7bc,
    "https://tile.openstreetmap.org/{z}.
    {"attribution": "\u0026copy; \u003c
```

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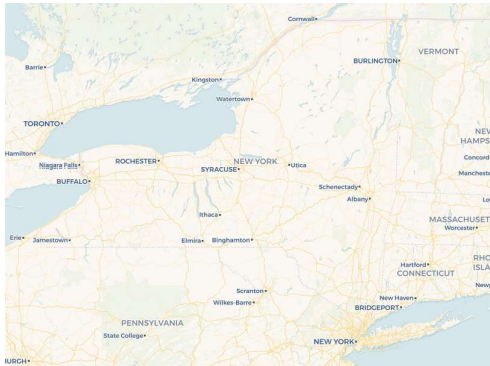
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Map

```
world_ny_voyager = folium.Map(location=(42.9525, -76.01667),
                                zoom_start=7, tiles='CartoDB Voyager')
world_ny_voyager.save("world_ny_voyager.html")
```

- Folium default tiles are set to OpenStreetMap
- Other included tile sets:
 - CartoDB Positron
 - CartoDB Voyager
 - NASAGIBS Blue Marble
- Check the API for details on free basemap providers

<https://python-visualization.github.io/folium/latest/reference.html>



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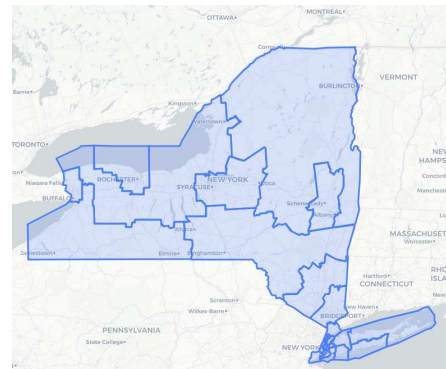
Adding District Boundary Data to a Map

```
import folium
import os
import geopandas as gpd
ny_cd = gpd.read_file('ny_cong_adopted_2022.zip')
ny_cd.to_file('myJson.geojson', driver='GeoJSON')
ny_cd_gj = gpd.read_file('myJson.geojson')
nys=folium.Map(tiles="cartoDB positron",
               location=(42.9525, -76.01667), zoom_start=7)
folium.GeoJson(ny_cd_gj).add_to(nys)
nys.save("nys.html")
```

Reads the Shapefile

Adds the GeoJson to the map

Parameter to folium.GeoJson can be a
GeoJSON or a GeoDataFrame (and others)



nys.html

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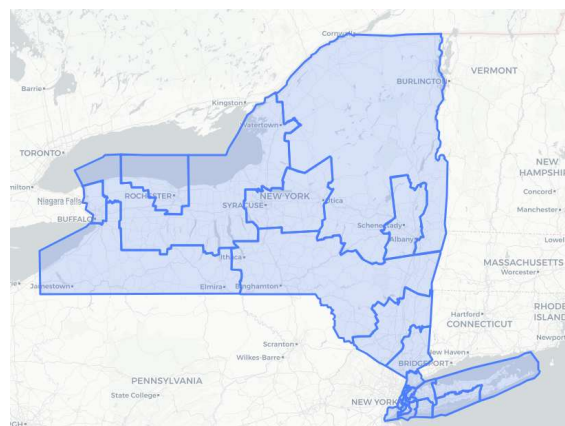
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Extended - Are We on Track?

- Import a district boundary file for your favorite state
- If the file is in Shapefile format, convert to GeoJSON
- Build and save the html file containing your folium map for your state
- Use a map layer other than Open Streets
- Display in your browser



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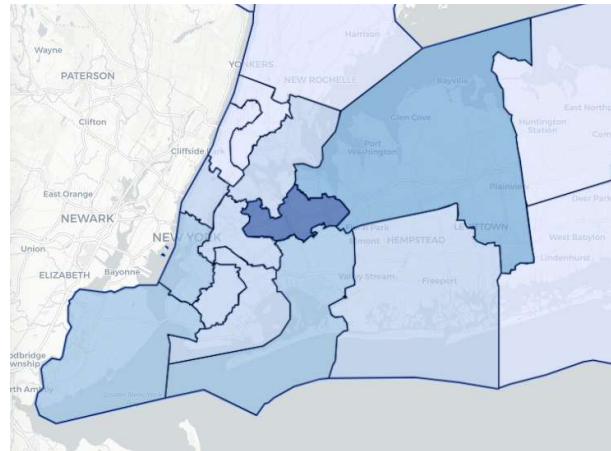
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Choropleth Maps

- Definition – a map that uses color to represent some quantity associated with fixed regions in the map
- Usually aggregated into standard geographical units such as counties, Congressional districts, states, etc.
- Order of the variable should be reflected in the perceived order of the colors (e.g., light to dark)
- Colors should be easily distinguishable, which usually limits the number of discrete colors (e.g., 7)

NYS Asian-American Population



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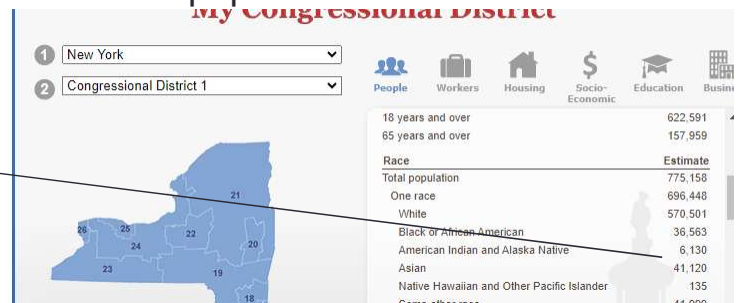
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Adding Data to a Folium Map ...

- We will show how to add information to the map about the Asian-American population in each Congressional district
- First, we create a DataFrame with the population data

```
asian_pop = pd.DataFrame.from_dict({
    '1': 41120,
    '2': 26465,
    '3': 191395,
    ...
    '26': 44604
}, orient='index').reset_index()
```



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Python

- DataFrame.from_dict constructs a DataFrame object from a Python dictionary
- Python dictionary is a data structure used to store key/value pairs
- Written in curly brackets
- Orient parameter defines the keys as rows in the DataFrame
- reset_index() resets the row labels and then sets the keys as a column

```
asian_pop = pd.DataFrame.from_dict({
    '1': 41120,
    '2': 26465,
    '3': 191395,
    ...
    '26': 44604
}, orient='index').reset_index()
```

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... Adding Data to a Folium Map ...

```
...
asian_pop.columns=['DISTRICT', 'Asian Population']
folium.Choropleth(
    geo_data = ny_cd_gj,
    data = asian_pop,
    columns = ['DISTRICT', 'Asian Population'],
    key_on = 'feature.properties.DISTRICT').add_to(nys)
nys.save('nys_default_chor.html')
```

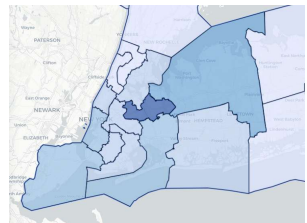
GeoJSON or GeoDataFrame that contains the district boundaries

DataFrame that contains the data values to be displayed

The key (or label) in ny_cd_gj to bind the data to

Columns from the DataFrame to use

Blue is the default colormap



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Customize Your Choropleth

- Your generated choropleth map should emphasize aspects of your data and highlight your message
- You can customize your choropleth in many ways, including
 - Colormap
 - Opacity
 - Color bar

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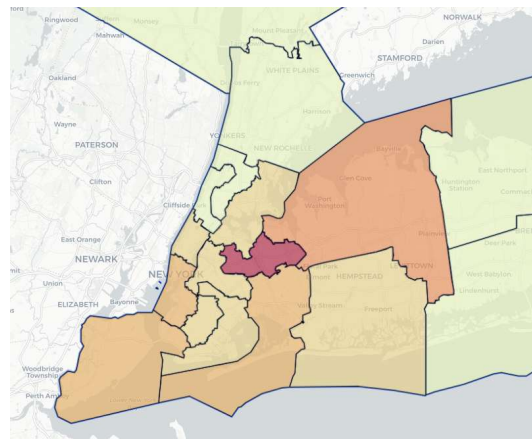
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Choropleth Colormap

- Look through different colormaps in ColorBrewer (<https://colorbrewer2.org/>)
- Update your track code to use a ColorBrewer colormap as in

```
folium.Choropleth(
    geo_data = ny_cd_gj,
    data = asian_pop,
    columns = ['DISTRICT', 'Asian Population'],
    fill_color='YlOrRd',
    key_on = 'feature.properties.DISTRICT').add_to(nys)
nys.save('nys_chor.html')
```



Which colormap and # data classes look best?

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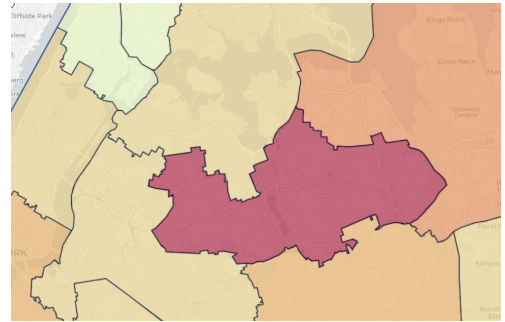
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Opacity

- Definition – condition of lacking transparency
- You can specify both fill and line opacity by setting an attribute to a value between 0 and 1
 - 0 is fully transparent
 - 1 is fully opaque

```
folium.Choropleth(
    geo_data = ny_cd_gj,
    data = asian_pop,
    columns = ['DISTRICT', 'Asian Population'],
    fill_color='YlOrRd',
    fill_opacity = .1,
    line_opacity = .8,
    key_on = 'feature.properties.DISTRICT').add_to(nys)
nys.save('nys_chor.html')
```



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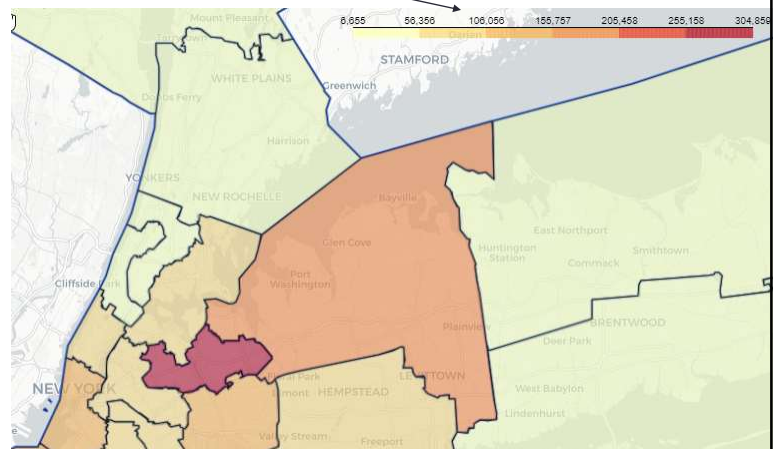
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Color Bar ...

- You can customize the data ranges assigned to each color to
 - Make the color ranges more regular
 - Emphasize certain regions
 - Include legend text

Default Color Bar



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... Color Bar

```
folium.Choropleth(  
    geo_data = ny_cd_gj,  
    data = asian_pop,  
    columns = ['DISTRICT', 'Asian Population'],  
    fill_color='YlOrRd',  
    fill_opacitty = .1,  
    line_opacity = .8,  
    bins = [0, 50000, 100000, 150000, 200000, 250000, 300000, 350000],  
    legend_name = 'Asian American Population',  
    key_on = 'feature.properties.DISTRICT').add_to(nys)  
nys.save('nys_chor.html')
```

