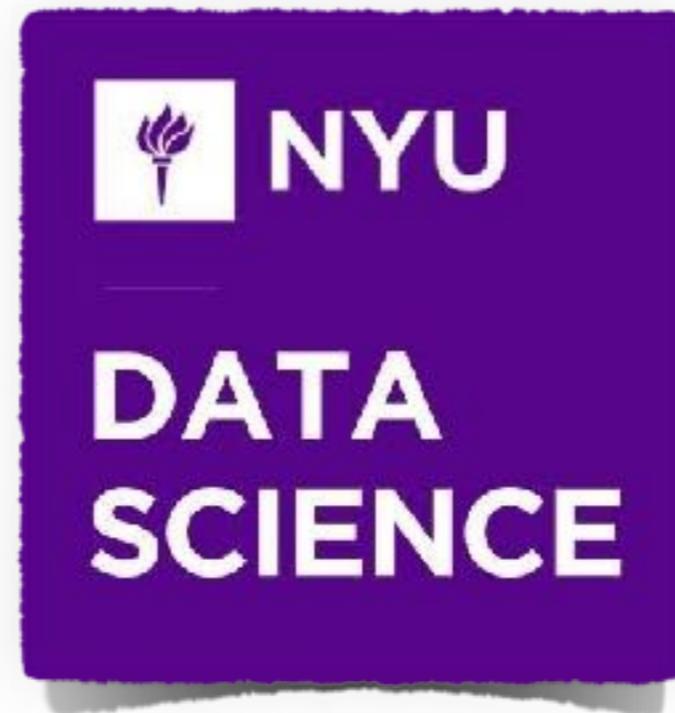


<https://bmtgoncalves.github.io/TorinoCourse/>

Lecture IV - Geocoding and Spatial Analysis

Bruno Gonçalves
www.bgoncalves.com



Google Credentials

The screenshot shows the Google Cloud Platform API Manager interface. The left sidebar has 'API Manager' selected, with 'Credentials' highlighted. The main area is titled 'Credentials' and includes tabs for 'Credentials', 'OAuth consent screen', and 'Domain verification'. A 'Create credentials' button is visible. A dropdown menu is open over the 'Create credentials' button, listing four options: 'API key', 'OAuth client ID', 'Service account key', and 'Help me choose'. Below this, there's a section for 'OAuth 2.0 client IDs' with a table showing one entry: 'Test' (Creation date: Apr 20, 2017, Type: Other). To the right, there are sections for 'Key' and 'Client ID', each with a large input field and edit/delete icons.

We'll need both an API Key
and the OAuth client ID.

Google Credentials

S Create client ID - Torino X Bruno

Secure https://console.developers.google.com/apis/credentials/oauthclient?project=torino-164320

Google APIs Torino

API Manager Create client ID

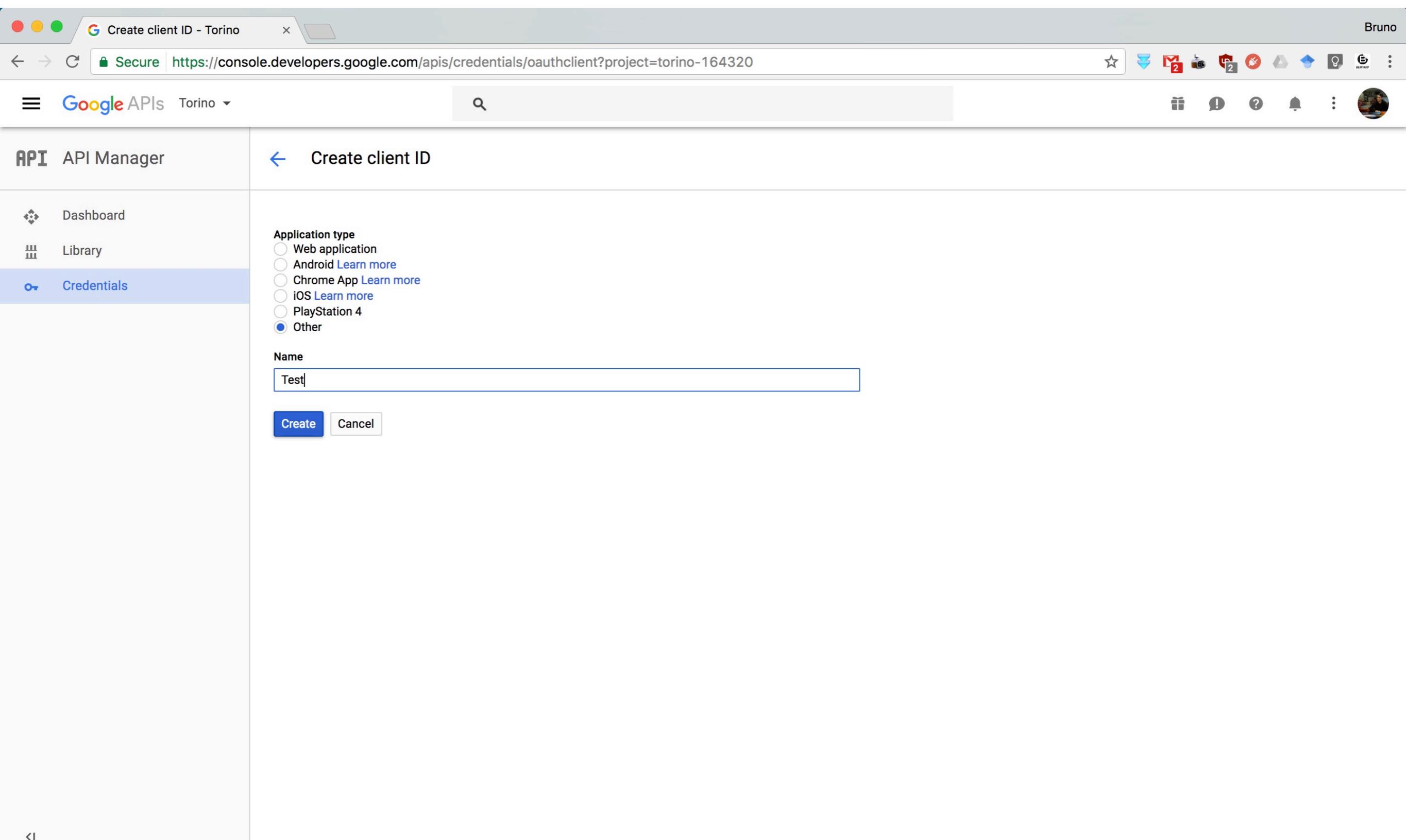
Application type

- Web application
- Android [Learn more](#)
- Chrome App [Learn more](#)
- iOS [Learn more](#)
- PlayStation 4
- Other

Name

Test

Create Cancel



Google Credentials

Screenshot of the Google Cloud Platform API Manager Credentials page.

The page title is "Credentials - Torino". The URL is <https://console.developers.google.com/apis/credentials?highlightClient=999349363357-bdd0p2tv4sljbqp38jp6mud7maqtavk5.apps.googleusercontent.com>.

The left sidebar shows "API Manager" with sections: Dashboard, Library, and Credentials (selected).

The main content area is titled "Credentials" and includes tabs: Credentials (selected), OAuth consent screen, and Domain verification.

Buttons: "Create credentials" (dropdown menu) and "Delete".

Text: "Create credentials to access your enabled APIs. Refer to the API documentation for details."

Table headers: API keys and OAuth 2.0 client IDs.

Table rows:

- API keys:**
 - Name: [checkbox]
 - API key: [checkbox]
- OAuth 2.0 client IDs:**
 - Name: [checkbox]
 - Test: [checkbox] (Created: Apr 2, 2017)
 - Test: [checkbox] (Created: Apr 2, 2017)

A modal dialog box is displayed in the center, titled "OAuth client". It contains the message "Here is your client ID" and a text input field. An "OK" button is at the bottom right of the modal.

Google Credentials

The screenshot shows the Google Cloud Platform API Manager Credentials page. The left sidebar is titled "API Manager" and includes "Dashboard", "Library", and "Credentials". The main area is titled "Credentials" and has tabs for "Credentials", "OAuth consent screen", and "Domain verification". A "Create credentials" button is highlighted in blue. Below it, a note says "Create credentials to access your enabled APIs. Refer to the API documentation for details." A modal window titled "API key created" is open, containing the message "Use this key in your application by passing it with the `key=API_KEY` parameter." It also displays "Your API key" with a text input field and a warning: "⚠ Restrict your key to prevent unauthorized use in production." At the bottom of the modal are "CLOSE" and "RESTRICT KEY" buttons. The background shows lists for "API keys" and "OAuth 2.0 client IDs".

Credentials - Torino

Secure https://console.developers.google.com/apis/credentials?highlightClient=999349363357-bdd0p2tv4sljbqp38jp6mud7maqtavk5.apps.googleusercontent.com

Google APIs Torino

Bruno

API Manager

Credentials

Credentials OAuth consent screen Domain verification

Create credentials Delete

Create credentials to access your enabled APIs. Refer to the API documentation for details.

API keys

Name	Created	Action
API key 2	Apr 20, 2017	
API key	Apr 20, 2017	

OAuth 2.0 client IDs

Name	Created	Action
Test	Apr 20, 2017	
Test	Apr 20, 2017	

API key created

Use this key in your application by passing it with the `key=API_KEY` parameter.

Your API key

⚠ Restrict your key to prevent unauthorized use in production.

CLOSE RESTRICT KEY

API Authorization

Screenshot of the Google API Manager interface showing the Google Static Maps API page.

The page title is "Google Static Maps API". There is a "ENABLE" button. On the left, there is a sidebar with "Dashboard" selected, and "Library" and "Credentials" options.

About this API: Place a Google Maps image on your webpage without requiring JavaScript or any dynamic page loading with the Google Static Maps API. This service creates your map based on URL parameters sent through a standard HTTP request and returns the map as an image.

Using credentials with this API:

Using an API key: To use this API you need an API key. An API key identifies your project to check quotas and access. Go to the Credentials page to get an API key. You'll need a key for each platform, such as Web, Android, and iOS. [Learn more](#)

A diagram illustrating the flow of data between an application and Google services. It shows a purple smartphone icon with '</>' symbols next to a teal circular icon containing a white key symbol. Arrows point from the phone to the key icon, and from the key icon to a stack of three rectangular boxes representing a Google service.

Each API has to be
“Enabled” for this specific set
of credentials

API Authorization

The screenshot shows the Google API Manager interface for the 'Torino' project. The main navigation bar includes 'Google APIs' and 'Torino'. The left sidebar has 'Dashboard' selected, along with 'Library' and 'Credentials'. The main content area is titled 'Google Static Maps API' with a 'DISABLE' button. It features tabs for 'Overview' (selected), 'Quotas', and 'URL signing secret'. Below these are sections for 'About this API', 'Traffic' (showing 'Requests/sec (5 min average)' and a message 'There is no data for this API in this time span'), and 'Errors' (showing 'Percent of requests' and a similar message). The top right corner shows the user's name 'Bruno' and various browser extension icons.

Secure https://console.developers.google.com/apis/api/static_maps_backend/overview?project=torino-164320&duration=PT1H

Google APIs Torino

API Manager

Google Static Maps API

DISABLE

Overview Quotas URL signing secret

About this API Documentation

All API versions All API credentials All API methods 1 hour 6 hours 12 hours 1 day 2 days 4 days 7 days 14 days 30 days

Traffic By response code

Requests/sec (5 min average)

There is no data for this API in this time span

Errors

Percent of requests

There is no data for this API in this time span

Google Maps APIs

<https://github.com/googlemaps/google-maps-services-python>

- As before, we store our credentials in a dictionary kept in an external file

```
accounts = {
    "torino": {
        "api_key": "API_KEY",
        "client_id": "CLIENT_ID",
        "client_secret": "CLIENT_SECRET"
    }
}
```

- Google provides dozens of different APIs for various purposes.
- The [googlemaps](#) Python library provides easy access to some of the GIS related ones:
 - Directions API
 - Distance Matrix API
 - Elevation API
 - Geocoding API
 - Geolocation API
 - Time Zone API
 - Roads API
 - Places API

Google Maps APIs

<https://github.com/googlemaps/google-maps-services-python>

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```
accounts = {
    "torino": {
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        "client_id": "CLIENT_ID",
        "client_secret": "CLIENT_SECRET"
    }
}
```

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 - Distance Matrix API
 - Elevation API
 - Geocoding API
 - Geolocation API
 - Time Zone API
 - Roads API
 - Places API

Google Geocoding API

<https://developers.google.com/maps/documentation/geocoding/start>

- Allows us to obtain the latitude and longitude of a specific location.

```
import googlemaps
from google_accounts import accounts

app = accounts["torino"]
gmaps = googlemaps.Client(key=app["api_key"])

geocode_result = gmaps.geocode('JFK Airport')

print(geocode_result[0]["geometry"]["location"])
```

- As with previous APIs, it returns a JSON object with a list of results.
- Each result provides detailed information such as the address, type of location and a unique id.
- Within the **"geometry"** field there is:
 - a **"location"** field with the **latitude** and **longitude**.
 - a **"viewport"** field with the northeast and southwest coordinates of the respective **bbox**.
- The **"type_id"** can be used with the **Places API** to obtain further information, reviews, etc...

Google Geocoding API

<https://developers.google.com/maps/documentation/geocoding/start>

```
[{"address_components": [{"long_name": "John F. Kennedy International Airport",  
    "short_name": "John F. Kennedy International Airport",  
    "types": ["airport",  
              "establishment",  
              "point_of_interest"]},  
   {"long_name": "Queens",  
    "short_name": "Queens",  
    "types": ["political",  
              "sublocality",  
              "sublocality_level_1"]},  
   {"long_name": "Queens County",  
    "short_name": "Queens County",  
    "types": ["administrative_area_level_2",  
              "political"]},  
   {"long_name": "New York",  
    "short_name": "NY",  
    "types": ["administrative_area_level_1",  
              "political"]},  
   {"long_name": "United States",  
    "short_name": "US",  
    "types": ["country", "political"]}],  
  {"long_name": "11430",  
   "short_name": "11430",  
   "types": ["postal_code"]}],  
  "formatted_address": "John F. Kennedy International Airport, Queens, NY  
  11430, USA",  
  "geometry": {"location": {"lat": 40.641311, "lng": -73.77813909999999},  
              "location_type": "APPROXIMATE",  
              "viewport": {"northeast": {"lat": 40.64266008029149,  
                                      "lng": -73.7767901197085},  
                          "southwest": {"lat": 40.63996211970849,  
                                      "lng": -73.7794880802915}}},  
  "place_id": "ChIJR0lA1VBmwokR8BGfSBoYt-w",  
  "types": ["airport", "establishment", "point_of_interest"]}]
```

Google Reverse Geocoding

<https://developers.google.com/maps/documentation/geocoding/start>

- Allows us to discover what a given set of coordinates represents
- `.reverse_geocode(lat, lon)` - Just requires a lat/lon tuple.
- Google has access to many layers of GIS information and the results reflect this. The output is a list of results at various degrees of precision.
 - Building,
 - Nearest Road
 - County
 - Zip code
 - State
 - Country
 - etc...

Google Reverse Geocoding

<https://developers.google.com/maps/documentation/geocoding/start>

```
{'address_components': [{ 'long_name': 'New York',
                           'short_name': 'New York',
                           'types': ['locality', 'political']},
                        { 'long_name': 'New York',
                           'short_name': 'NY',
                           'types': ['administrative_area_level_1', 'political']},
                        { 'long_name': 'United States',
                           'short_name': 'US',
                           'types': ['country', 'political']}],
 'formatted_address': 'New York, NY, USA',
 'geometry': {'bounds': {'northeast': {'lat': 40.9175771,
                                         'lng': -73.70027209999999},
                           'southwest': {'lat': 40.4773991,
                                         'lng': -74.25908989999999}},
              'location': {'lat': 40.7127837, 'lng': -74.0059413},
              'location_type': 'APPROXIMATE',
              'viewport': {'northeast': {'lat': 40.9152555,
                                         'lng': -73.70027209999999},
                           'southwest': {'lat': 40.4960439,
                                         'lng': -74.2557349}}},
 'place_id': 'ChIJQwg_06VPwokRYv534QaPC8g',
 'types': ['locality', 'political']}
```

Challenge - Google Reverse Geocoding

<https://developers.google.com/maps/documentation/geocoding/start>

- Reverse Geocode the coordinates:

40.6413111,-73.77813909999999

- and print the “types” and “formated_address” of each of the results

Challenge - Google Reverse Geocoding

<https://developers.google.com/maps/documentation/geocoding/start>

- Reverse Geocode the coordinates:

40.6413111,-73.77813909999999

- and print the “types” and “formated_address” of each of the results

```
import googlemaps
from google_accounts import accounts

app = accounts["torino"]
gmaps = googlemaps.Client(key=app["api_key"])

reverse_result = gmaps.reverse_geocode((40.6413111,-73.7781390999999))

for result in reverse_result:
    print(result["types"], result["formatted_address"])
```

Google Reverse Geocoding

A screenshot of a Google Maps search results page. The search bar at the top shows the coordinates $40^{\circ}38'28.7^{\prime\prime}\text{N } 73^{\circ}46'41.3^{\prime\prime}\text{W}$. The main map view shows the area around JFK Terminal 4, featuring yellow-highlighted airport gates for Emirates Airline, Delta, and Virgin America. To the west, a yellow-highlighted area includes the Shake Shack and Buffalo Wild Wings. A red location pin is placed near the bottom center of the map, with the text "37 min drive - home". The map interface includes standard controls for zooming and panning, and a sidebar on the left provides options to save the place, view nearby locations, send it to your phone, or add a missing place or label.

40°38'28.7"N 73°46'41.3"W
40.6413111, -73.778139

Directions

SAVE NEARBY SEND TO YOUR PHONE SHARE

Add a missing place Add a label

Satellite

Emirates Airline
JFK Terminal 4
Delta
Virgin America JFK
Shake Shack
Buffalo Wild Wings
Uptown Brasserie
Travelex Currency Services

Perimeter Rd
Perimeter Rd

Google

Map data ©2017 Google Terms www.google.com/maps Send feedback 100 m

Google Reverse Geocoding

```
import json
import matplotlib.pyplot as plt
import matplotlib.patches as patches

reverse_result = json.load(open('reverse.json'))

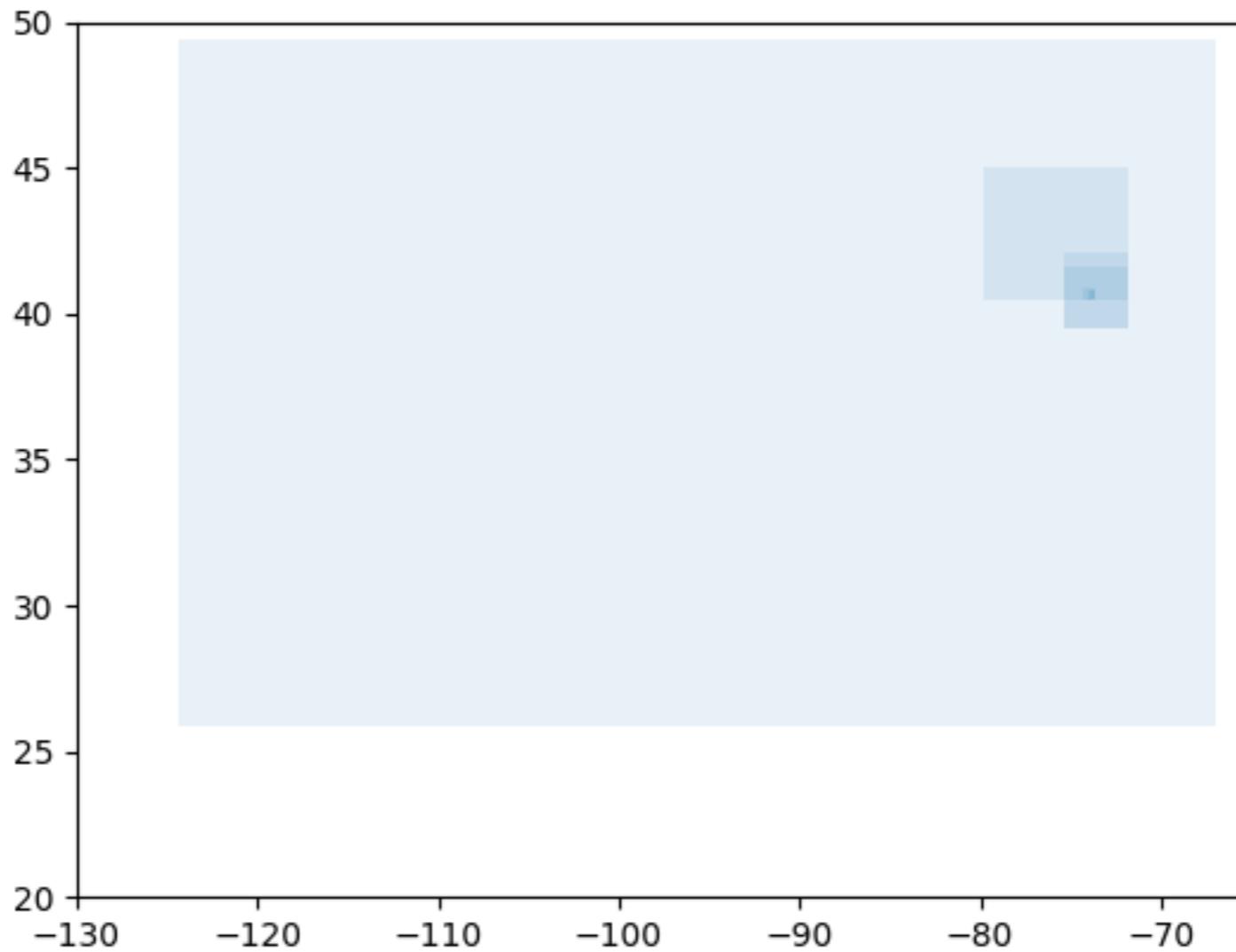
plt.figure()
plt.xlim(-130,-65)
plt.ylim(20,50)
currentAxis = plt.gca()

for result in reverse_result:
    viewport = result["geometry"]["viewport"]
    xy = (viewport['southwest']['lng'], viewport['southwest']['lat'])
    width = viewport['northeast']['lng']-viewport['southwest']['lng']
    height = viewport['northeast']['lat']-viewport['southwest']['lat']

    currentAxis.add_patch(patches.Rectangle(xy, width, height, alpha=.1))

plt.savefig('reverse.png')
```

Google Reverse Geocoding



Google Places

<https://developers.google.com/places/>

- Provides information about specific venues and locations
- `.place(place_id)` - Information about a specific `place_id`
- `.places(query, location=None, radius=None, page_token=None)` - query google maps for places within a certain radius of a given location
 - `location` - lat/long coordinates
 - `radius` - distance in meters
 - `page_token` - the token to paginate through the results
- Other options are also available to define price range, result language, type of result, etc...

```
[  
    'html_attributions',  
    'results',  
    'status',  
    'next_page_token']
```

Google Places

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 - `location` - lat/long coordinates
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 - `page_token` - the token to paginate through the results
- Other options are also available to define price range, result language, type of result, etc...

```
[  
    'html_attributions',  
    'results',  
    'status',  
    'next_page_token']
```

Google Places

<https://developers.google.com/places/>

```
['types',
'id',
'place_id',
'address_components',
'international_phone_number',
'name',
'reviews',
'adr_address',
'vecinity',
'url',
'utc_offset',
'website',
'geometry',
'reference',
'rating',
'scope',
'formatted_address',
'photos',
'icon',
'formatted_phone_number']
```

Google Places

<https://developers.google.com/places/>

```
['types',                                     ['airport', 'point_of_interest', 'establishment']
'id',
'place_id',
'address_components',
'international_phone_number',
'name',                                         'John F. Kennedy International Airport'
'reviews',
'adr_address',
'vicinity',
'url',
'utc_offset',
'website',
'geometry',                                     {'location': {'lat': 40.64131109999999, 'lng': -73.77813909999999},
'reference',                                 'viewport': {'northeast': {'lat': 40.67117114999999, 'lng': -73.76339675},
'rating',
'scope',
'formatted_address',
'photos',
'icon',
'formatted_phone_number']
```

Challenge - Google Places

<https://developers.google.com/places/>

- Search for “**pizza**” within a **10km** radius of

45.090219, 7.659144

- and print the formatted address of the second page of results.

Challenge - Google Places

<https://developers.google.com/places/>

- Search for “pizza” within a **10km** radius of

45.090219, 7.659144

- and print the formatted address of the second page of results.

```
import googlemaps
from google_accounts import accounts
import time

app = accounts["torino"]
gmaps = googlemaps.Client(key=app["api_key"])

geocode_result = gmaps.places("pizza", (45.090219, 7.659144), 10000)
result = geocode_result["results"][0]
print(result["formatted_address"])

time.sleep(1)
page_token = geocode_result["next_page_token"]
geocode_result = gmaps.places(None, page_token=page_token)
result = geocode_result["results"][0]

print(result["formatted_address"])
```

Challenge - Google Places

<https://developers.google.com/places/>

```
{'formatted_address': 'Corso Peschiera, 312/A, 10139 Torino, Italy',
'geometry': {'location': {'lat': 45.07176469999999, 'lng': 7.6317175},
             'viewport': {'northeast': {'lat': 45.07308433029149,
                                       'lng': 7.633044980291503},
                          'southwest': {'lat': 45.0703863697085,
                                        'lng': 7.630347019708498}}},
'icon': 'https://maps.gstatic.com/mapfiles/place_api/icons/generic_business-71.png',
'id': '644f3c75d97ae5ec66ffca7a1d2a34a5a98abad4',
'name': 'Pizza Loca',
'opening_hours': {'open_now': True, 'weekday_text': []},
'place_id': 'ChIJnZx7tJJsieEcR4bCZfBz3VSS',
'rating': 5,
'reference': 'CmRRAAAAFdoEAMs_mvHc7wP6-2pJ_Qzs9Yw4u7aMi51cyk05rfITav2I-
r6gK_pDUAsfjxSJAf0YvIL0xaPZ7R_1XiFLJNyNiQ2TArhZMumL7J3B55CroVEQdNnbvHwsJmgT53DEhDkbpkUbiFn4Ntnj3G
3K_tgGhQNSiQrCbG8gAM1ZQii-zshdQgmbw',
'types': ['meal_delivery',
          'meal_takeaway',
          'restaurant',
          'food',
          'point_of_interest',
          'establishment']}
```

Google Directions

<https://developers.google.com/maps/documentation/directions/>

- Provides step by step directions from point A to point B.
- Directions are always for the shortest path
- `.directions((start_lat, start_lon), (end_lat, end_lon))` - Directions between two sets of GPS coordinates
- `.directions("start_address", "end_address")` - Geolocate each address and provide directions from `start_address` to `end_address`.
- Each step of the journey comes with `start_location` and `end_location` GPS coordinates as well as `distance`, `duration` and `html_instructions`.

```
{'distance': {'text': '0.5 km', 'value': 464},  
 'duration': {'text': '2 mins', 'value': 98},  
 'end_location': {'lat': 45.5014209, 'lng': 9.1882349},  
 'html_instructions': 'Continue onto <b>Via Valassina</b>',  
 'polyline': {'points':  
  'eutGagaw@YGSG_AWq@Sc@MkFaBeDeAgDiAEA[M'],  
 'start_location': {'lat': 45.4974178, 'lng': 9.1865724},  
 'travel mode': 'DRIVING'}
```

Challenge - Google Directions

<https://developers.google.com/maps/documentation/directions/>

- Obtain the driving directions from coordinates:

45.067450, 7.685880

- to coordinates:

45.485895, 9.204283

- and print out all the **html_instructions**.

Challenge - Google Directions

<https://developers.google.com/maps/documentation/directions/>

- Obtain the driving directions from coordinates:

45.067450, 7.685880

- to coordinates
- ```
import googlemaps
from google_accounts import accounts

app = accounts["torino"]
gmaps = googlemaps.Client(key=app["api_key"])

directions = gmaps.directions((45.067450, 7.685880), (45.485895, 9.204283))

steps = directions[0]["legs"][0]["steps"]
```
- and print out
- ```
for step in steps:
    print(step["html_instructions"])
```

Google Directions

<https://developers.google.com/maps/documentation/directions/>

```
import googlemaps
from google_accounts import accounts
import matplotlib.pyplot as plt

app = accounts["torino"]
gmaps = googlemaps.Client(key=app["api_key"])

directions = gmaps.directions((45.485895, 9.204283), (45.067450, 7.685880))

steps = directions[0]["legs"][0]["steps"]

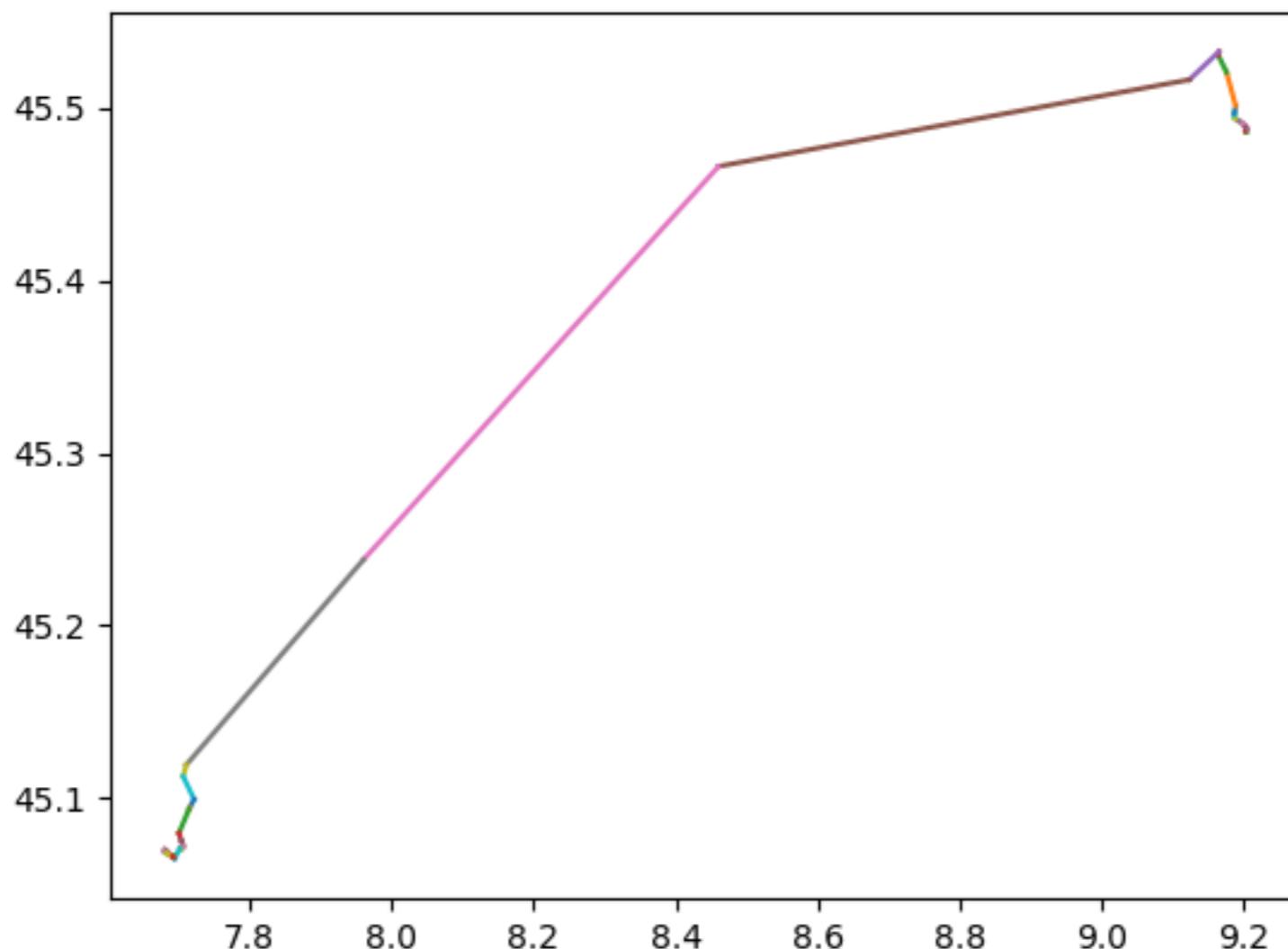
for step in steps:
    start = (step["start_location"]["lng"], step["start_location"]["lat"])
    stop = (step["end_location"]["lng"], step["end_location"]["lat"])

    plt.plot([start[0], stop[0]], [start[1], stop[1]])

plt.savefig('MiTo.png')
```

Google Directions

<https://developers.google.com/maps/documentation/directions/>



Google Directions

<https://developers.google.com/maps/documentation/directions/>

A screenshot of a Google Maps search results page. The top bar shows the URL as https://www.google.com/maps/dir/45.067450,+7.685880/45.485895,+9.204283/@45.2185152,7.8823616,9z/data=!4m10!4m9!1m3!2m2!... and the title "45.067450, 7.685880 to 45.485895, 9.204283". The left sidebar shows the starting point at 45.067450, 7.685880 and the destination at 45.485895, 9.204283. It includes options to "Leave now", "Send directions to your phone", and two route details: "via A4" (1 h 47 min, 89.8 miles) and "via E70 and A7" (2 h 11 min, 113 miles). The "via A4" route is highlighted in blue, while the "via E70 and A7" route is shown in grey. The main map area shows the route leading from the starting point through various Italian towns like Ivrea, Vercelli, and Pavia, ending near the destination. The map also features the Po River, Lake Maggiore, and the Matterhorn mountain. A "Satellite" view button is visible in the bottom left corner.

Google Distance Matrix

<https://developers.google.com/maps/documentation/distance-matrix/>

- Returns the travel time and distance for all pairs of origins and destinations
- Results are returned in rows, each row containing one origin paired with each destination.
- **.distance_matrix(origins, destinations)** - Both origins and destinations can be listed as either lat/long pairs or addresses
- Options for **mode** of transportation, **departure** or **arrival** time, etc...

Challenge - Google Distance Matrix

<https://developers.google.com/maps/documentation/distance-matrix/>

- Obtain the distance and time matrix from these origins:

(45.485895, 9.204283), (41.912199, 12.499857)

- to these destinations:

(45.067450, 7.685880), (43.775475, 11.257102)

- And print out the resulting object

Challenge - Google Distance Matrix

<https://developers.google.com/maps/documentation/distance-matrix/>

```
import googlemaps
from google_accounts import accounts
from pprint import pprint

app = accounts["torino"]
gmaps = googlemaps.Client(key=app["api_key"])

origins = [(45.485895, 9.204283), (41.912199, 12.499857)]
destinations = [(45.067450, 7.685880), (43.775475, 11.257102)]

matrix = gmaps.distance_matrix(origins, destinations)

pprint(matrix)
```

Google Distance Matrix

<https://developers.google.com/maps/documentation/distance-matrix/>

```
{'destination_addresses': ['Via Maria Vittoria, 12, 10123 Torino, Italy',
                            'Via Ricasoli, 26-30, 50122 Firenze, Italy'],
 'origin_addresses': ['Piazza Quattro Novembre, 581, 20124 Milano, Italy',
                      'Via Brescia, 23, 00198 Roma, Italy'],
 'rows': [{ 'elements': [{ 'distance': { 'text': '147 km', 'value': 147321 },
                         'duration': { 'text': '1 hour 54 mins', 'value': 6868 },
                         'status': 'OK'},
                        { 'distance': { 'text': '307 km', 'value': 306952 },
                         'duration': { 'text': '3 hours 23 mins', 'value': 12167 },
                         'status': 'OK'}]},
           { 'elements': [{ 'distance': { 'text': '690 km', 'value': 689739 },
                         'duration': { 'text': '6 hours 49 mins', 'value': 24521 },
                         'status': 'OK'},
                        { 'distance': { 'text': '276 km', 'value': 275684 },
                         'duration': { 'text': '3 hours 6 mins', 'value': 11163 },
                         'status': 'OK'}]}],
 'status': 'OK'}
```

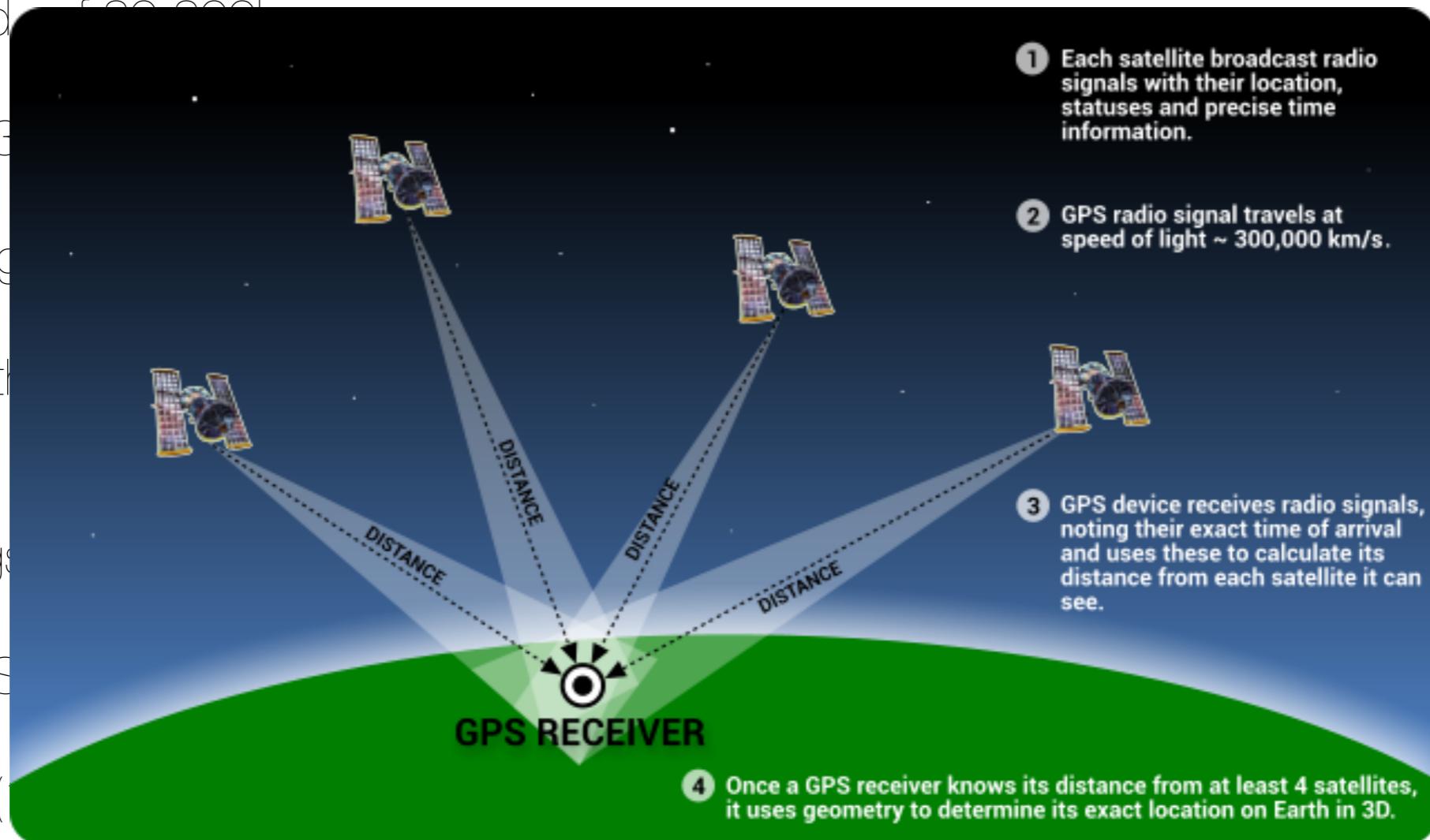
Geographical Information Systems

Global Positioning System (GPS)

- 32 satellites
- Orbital altitude of 20,200km
- Traveling at 3.9km/s
- Broadcasting their timestamped position
- Position on the ground is determined by GPS devices by triangulating information from 4 or more satellites.
- GPS belongs to the US government but other similar systems exist
 - GLONASS - Russia
 - BeiDou (1/2) - China
 - Galileo - Europe

Global Positioning System (GPS)

- 32 satellites
- Orbital altitude of 20,000 km
- Traveling at 3 km/s
- Broadcasting signals
- Position on the ground from 4 satellites.
- GPS belongs to:
 - GLONASS - Russia
 - BeiDou (BDS) - China
 - Galileo - Europe



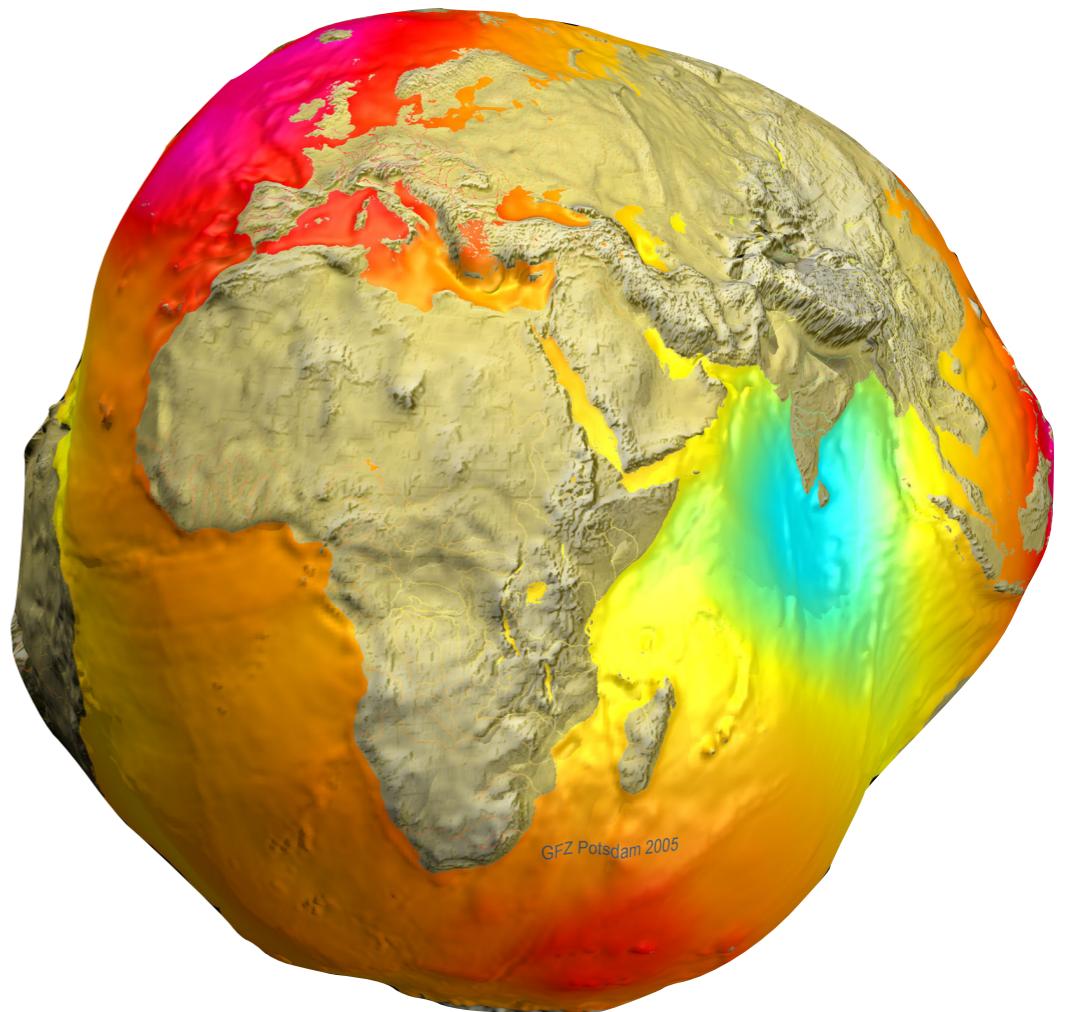
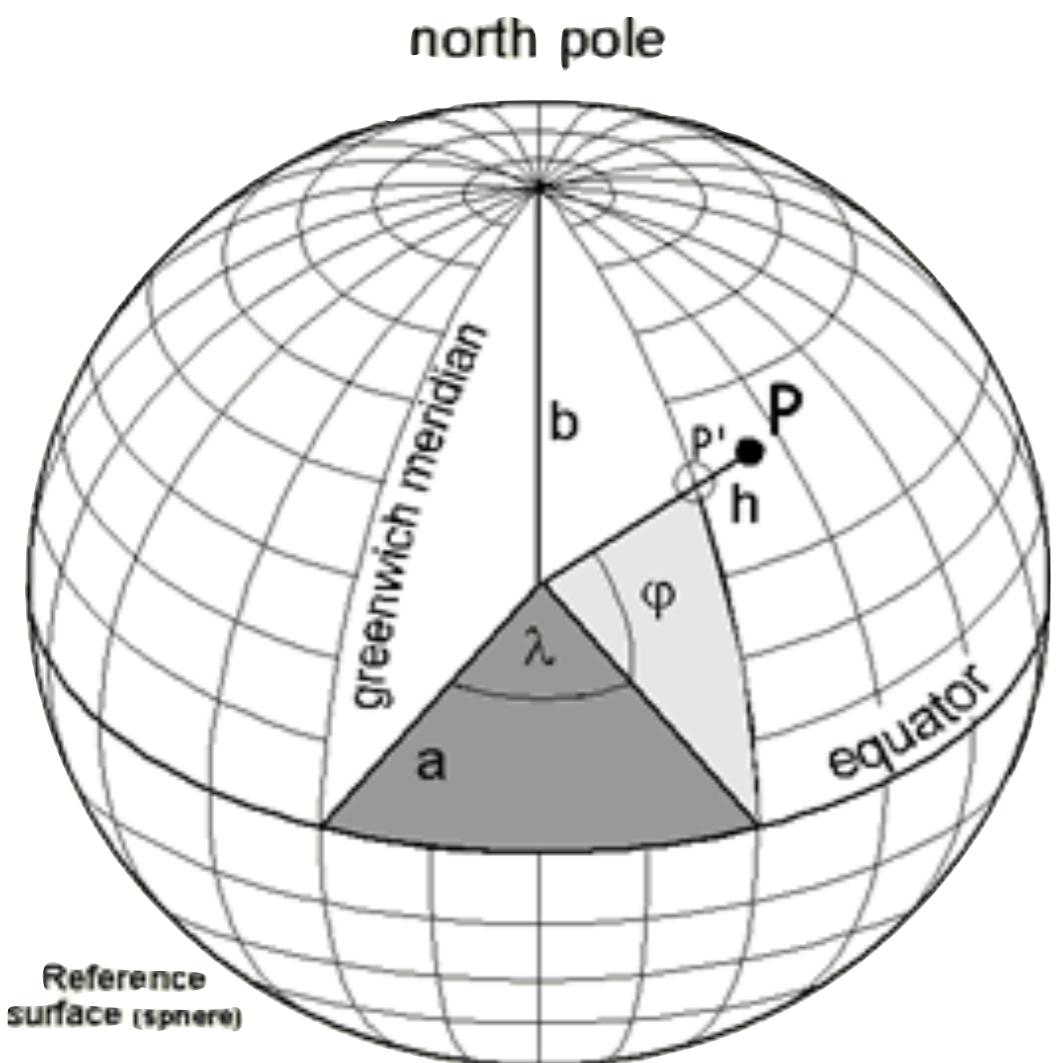
Global Positioning System (GPS)



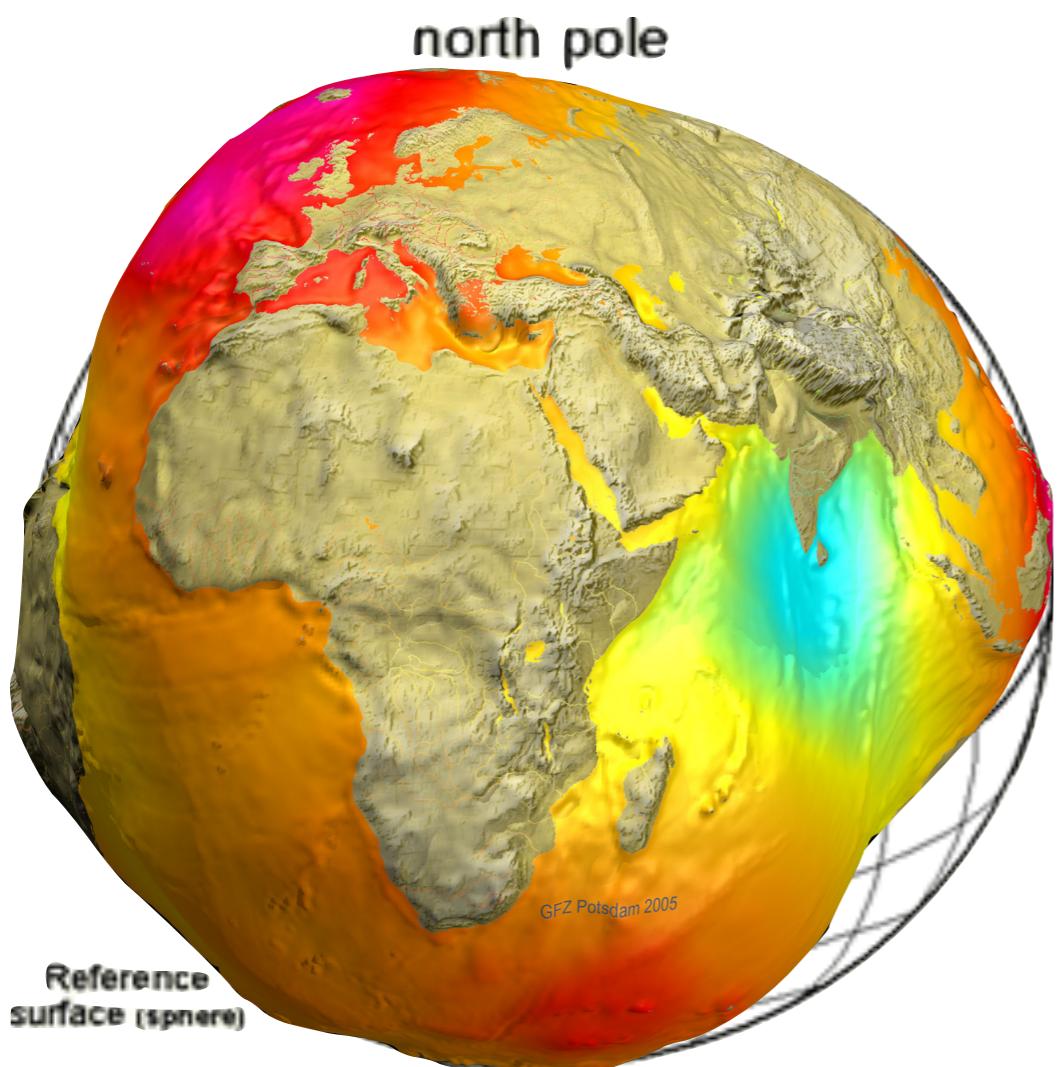
Global Positioning System (GPS)



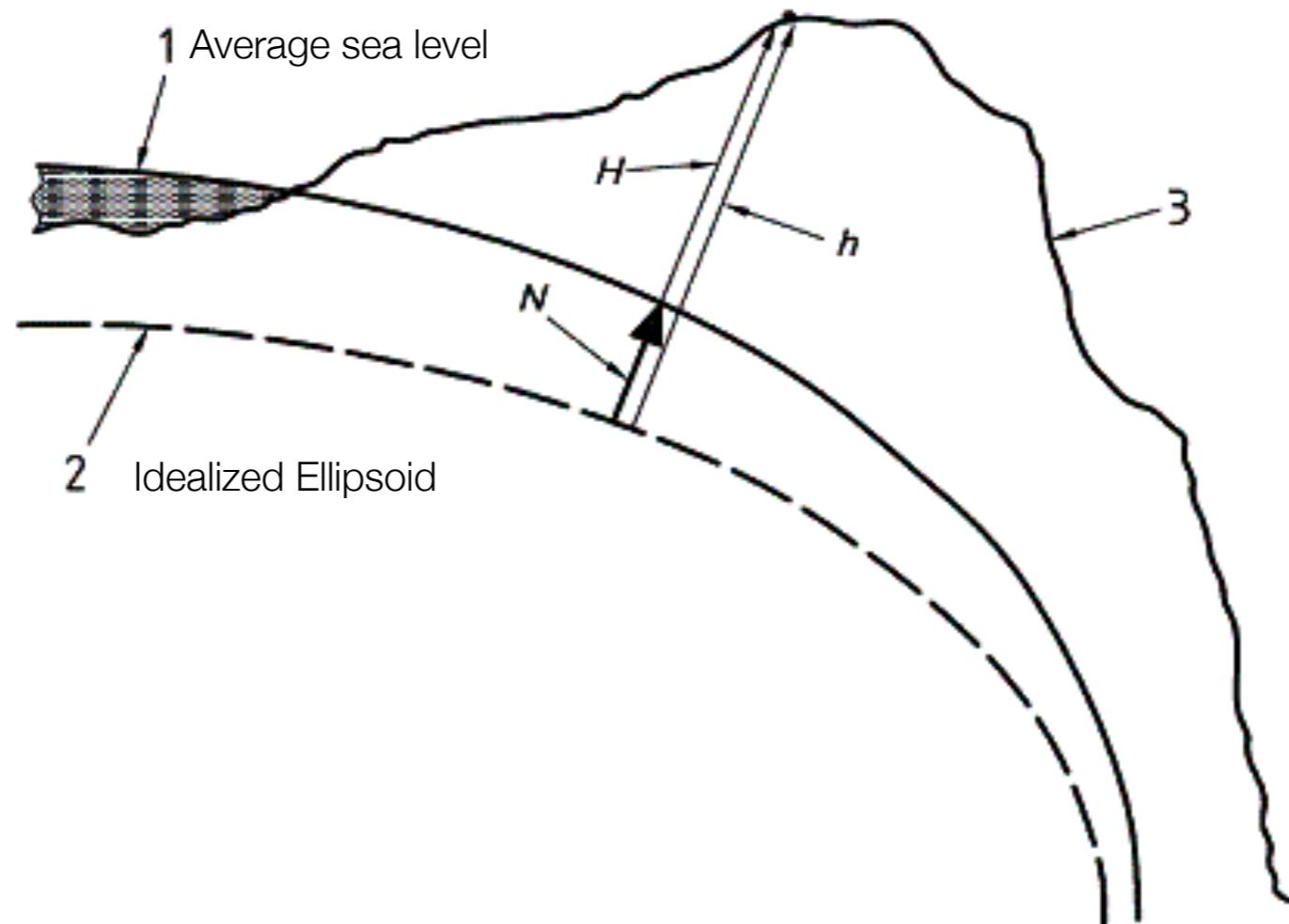
Global Positioning System (GPS)



Global Positioning System (GPS)



Global Positioning System (GPS)



Key

- 1 geoid
- 2 ellipsoid
- 3 surface of the Earth

h = ellipsoidal height, measured from ellipsoid along perpendicular passing through point; $h = H + N$

H = gravity-related height, measured along direction of gravity from vertical datum plane at geoid

N = geoid height, height of geoid above ellipsoid

WGS84

http://www.uenoosa.org/pdf/icg/2012/template/WGS_84.pdf

- "WGS 84 is an Earth-centered, Earth-fixed terrestrial reference system and geodetic datum"

Coordinate System: Cartesian Coordinates (X, Y, Z). WGS 84 (G1674) follows the criteria outlined in the International Earth Rotation Service (IERS) Technical Note 21. The WGS 84 Coordinate System origin also serves as the geometric center of the WGS 84 Ellipsoid and the Z-axis serves as the rotational axis of this ellipsoid of revolution. WGS 84 geodetic coordinates are generated by using its reference ellipsoid.

Defining Parameters: WGS 84 identifies four defining parameters. These are the semi-major axis of the WGS 84 ellipsoid, the flattening factor of the Earth, the nominal mean angular velocity of the Earth, and the geocentric gravitational constant as specified below.

Parameter	Notation	Value
Semi-major Axis	a	6378137.0 meters
Flattening Factor of the Earth	1/f	298.257223563
Nominal Mean Angular Velocity of the Earth	ω	7292115×10^{-11} radians/second
Geocentric Gravitational Constant (Mass of Earth's Atmosphere Included)	GM**	$3.986004418 \times 10^{14}$ meter ³ /second ²

**The value of GM for GPS users is 3.9860050×10^{14} m³/sec² as specified in the references below.

GIS Data Systems

Vector

- Data types:

- Points
- Lines
- Polygons

Raster

- Data types:

- Cells
- Pixels
- Elements

GIS Data Systems

Vector

- Data types:
 - Points
 - Lines
 - Polygons
- Discrete shapes and boundaries
- Spatial, Database and Network analysis
- Shapefile, GeoJSON, GML, etc...

Raster

- Data types:
 - Cells
 - Pixels
 - Elements
- Dense data, Continuous surfaces
- Spatial Analysis and modeling
- GeoTIFF, ASC, JPEG2000, etc...

GIS Data Systems

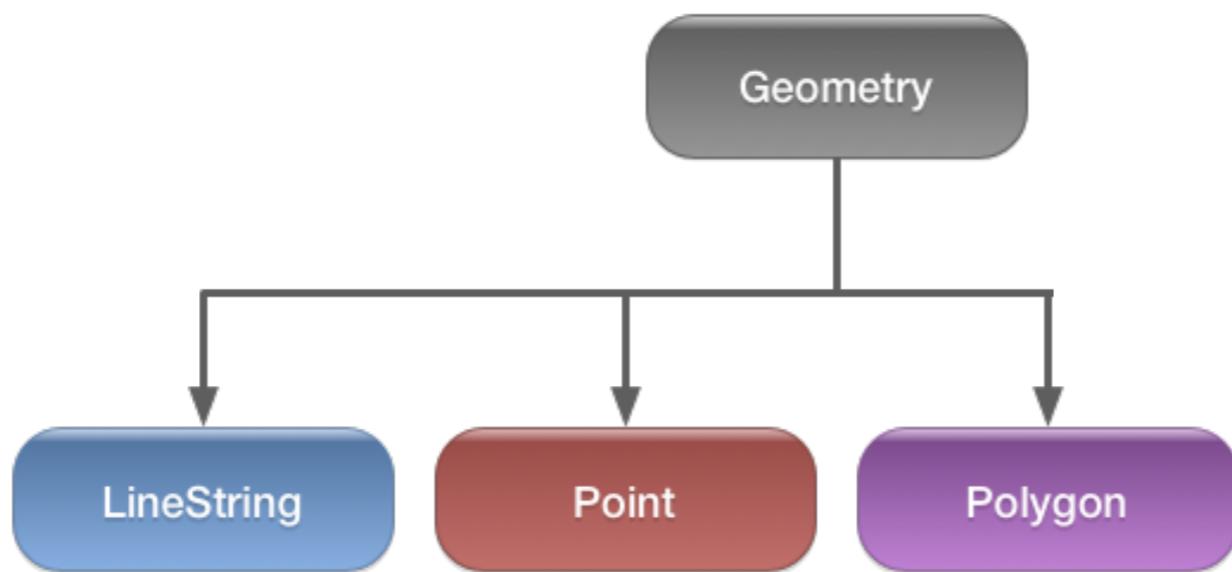
Vector

- Data types:
 - Points
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 - Polygons
- Discrete shapes and boundaries
- Spatial, Database and Network analysis
- Shapefile, GeoJSON, GML, etc...

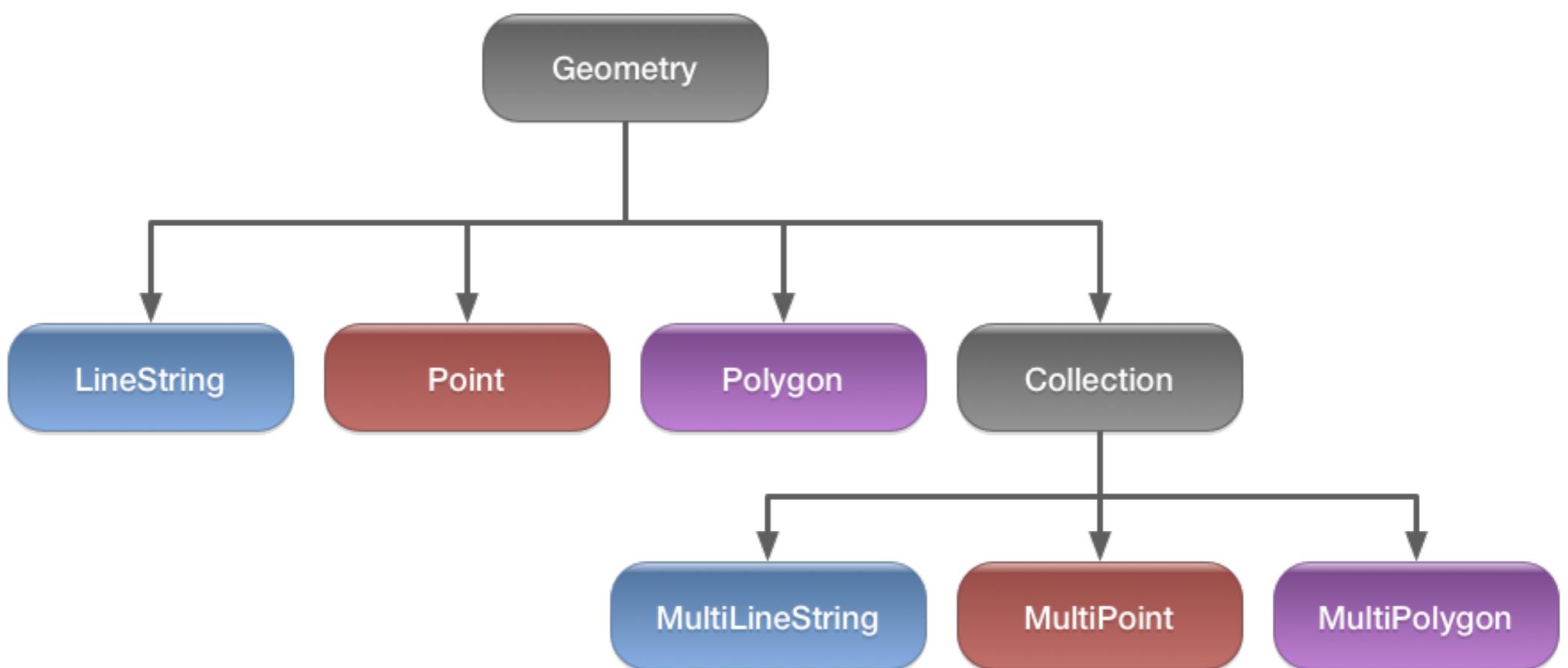
Raster

- Data types:
 - Cells
 - Pixels
 - Elements
- Dense data, Continuous surfaces
- Spatial Analysis and modeling
- GeoTIFF, ASC, JPEG2000, etc...

GIS Vector Data types

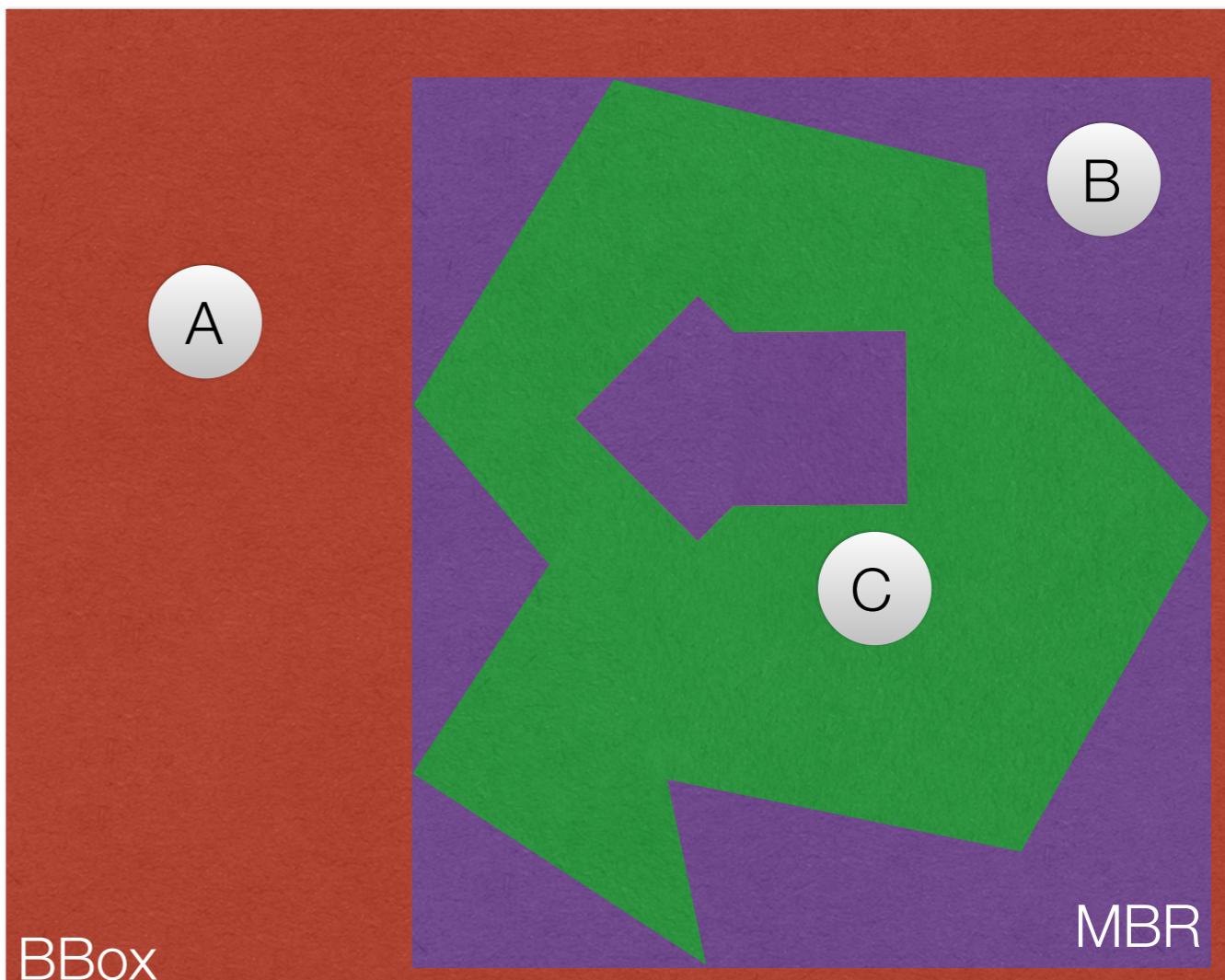


GIS Vector Data types



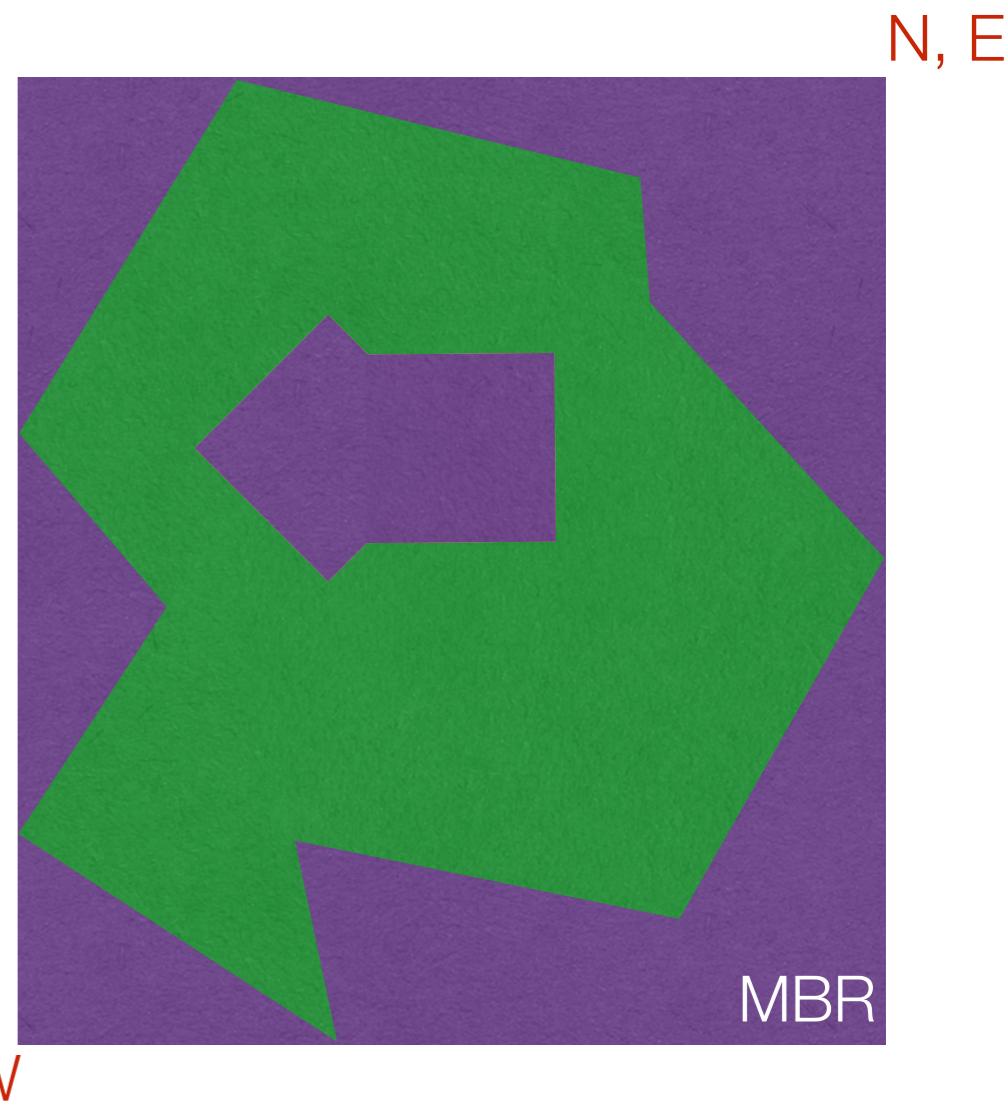
Fundamental Concepts

- **Bounding box** - A rectangular box containing the shape of interest
- **Minimum Bounding Rectangle** - The smallest possible Bounding Box that still contains the shape
- **Spatial Reference Identifier** - Maps "flat" lat/lon to a curved surface
 - Specially important to measure distances!
- Rectangles make it easy to quickly check relative positions, but lack precision
 - A within BBox but outside MBR
 - B within MBR but outside shape
 - C within shape
- If BBoxes don't overlap, neither do the shapes they contain



Get MBR/BBox

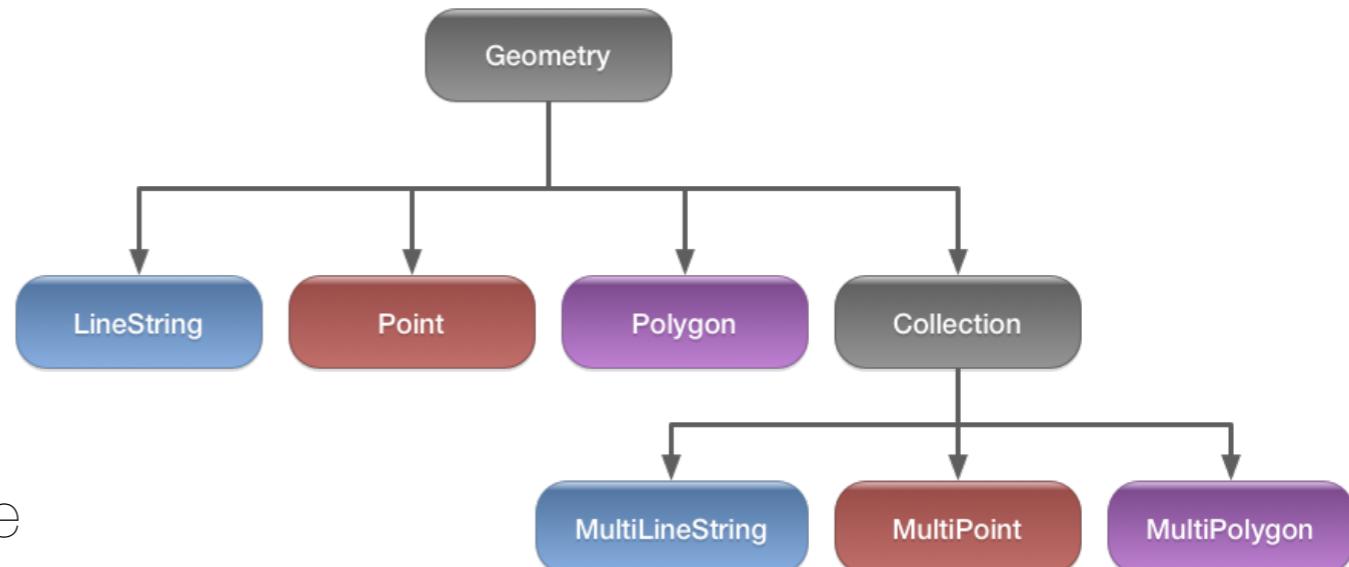
- You'll often see the term **BBox** to mean the **MBR**
- The MBR can be uniquely defined by the coordinates of two corners.
- Coordinates are simply the extreme values in the four "cardinal" directions, **North**, **South**, **East** and **West** of all the points defining the shape.



GeoJSON

<https://tools.ietf.org/html/rfc7946>

- A GeoJSON object is a JSON object specially tailored to spatial data
- It defines
 - Geometry - a region of space
 - Feature - a spatially bounded entity that contains a Geometry object
 - FeatureCollection - A list of Features
- Supports all types of GIS data types:
- Widely supported as an open standard online



GeoJSON

```
[ 'type' ,           'FeatureCollection'
  'crs' ,            {"properties": {"name": "urn:ogc:def:crs:EPSG::4258"},}
  'features' ]        "type": "name"}
```

GeoJSON

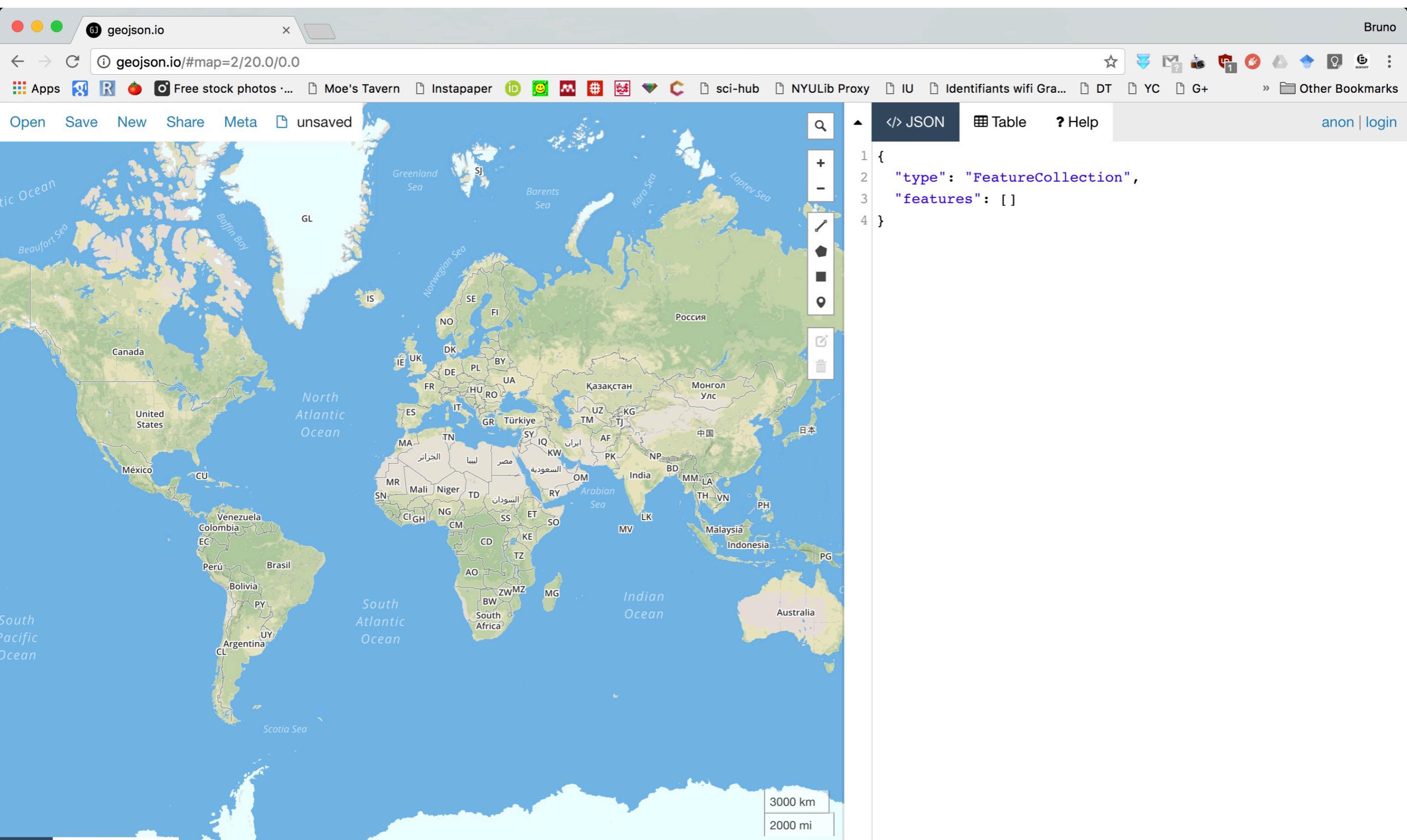
```
[ 'type',
  'crs',
  'features' ]  { 'geometry': { 'coordinates': [[[[[19.224069, 43.527541],
                                                [19.227058, 43.47903949800002],
                                                (...),
                                                [19.049223, 43.50178900100002],
                                                [19.224069, 43.527541]]]],
                                         'type': 'MultiPolygon'},
    'properties': { 'NUTS_ID': 'ME',
                    'SHAPE_AREA': 1.50797533788,
                    'SHAPE_LEN': 7.40877787465,
                    'STAT_LEVL_': 0},
    'type': 'Feature'}
```

GitHub support

A screenshot of a GitHub file viewer for 'layer_00.geojson' in the 'TorinoCourse' repository. The file contains a single line of code representing a GeoJSON map of Europe. The map is displayed as a blue outline on a light blue grid background. The GitHub interface includes a navigation bar with links for Code, Issues (0), Pull requests (0), Projects (0), Wiki, Pulse, Graphs, and Settings. Below the navigation bar, it shows the Branch: master dropdown, the file path TorinoCourse / Lecture IV / geofiles / layer_00.geojson, and two buttons for Find file and Copy path. A commit history section shows one commit by user bmtgoncalves titled 'Google Distance and Place Search' with commit hash 6d339cf and timestamp 3 hours ago. The commit details show 1 contributor. At the bottom, there are buttons for Raw, Blame, History, and a download icon. On the left side of the map area, there are zoom controls (+ and -) and a close button (-). The bottom left corner of the map area has the 'Mapbox' logo.

GeoJSON

geojson.io



Challenge - GeoJSON

- Write a short function to calculate the Bounding Box (MBR) from a GeoJSON file like the one in the **geofiles/** folder

Challenge - GeoJSON

```
def get_bbox(country):
    maxLat = None
    maxLon = None
    minLat = None
    minLon = None

    for polygon in country["geometry"]["coordinates"]:
        coords = np.array(polygon)[0]

        curMaxLat = np.max(coords.T[1])
        curMinLat = np.min(coords.T[1])

        curMaxLon = np.max(coords.T[0])
        curMinLon = np.min(coords.T[0])

        if maxLat is None or curMaxLat > maxLat:
            maxLat = curMaxLat

        if maxLon is None or curMaxLon > maxLon:
            maxLon = curMaxLon

        if minLat is None or curMinLat < minLat:
            minLat = curMinLat

        if minLon is None or curMinLon < minLon:
            minLon = curMinLon

    return maxLat, maxLon, minLat, minLon
```

Challenge - GeoJSON

```
def plot_country(country):
    for polygon in country["geometry"]["coordinates"]:
        coords = np.array(polygon)

        plt.plot(coords.T[0], coords.T[1])

    maxLat, maxLon, minLat, minLon = get_bbox(country)

    plt.xlim(minLon, maxLon)
    plt.ylim(minLat, maxLat)

data = json.load(open('geofiles/NUTS_RG_20M_2013.geojson'))

countries = {}

countries["crs"] = data["crs"]
countries["type"] = data["type"]
countries = {}

for feat in data["features"]:
    if feat["properties"]["STAT_LEVL_"] == 0:
        countries[feat["properties"]["NUTS_ID"]] = feat

country = countries["EL"]

plot_country(country)
plt.savefig('Greece.png')
```

shapefiles

<http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf>

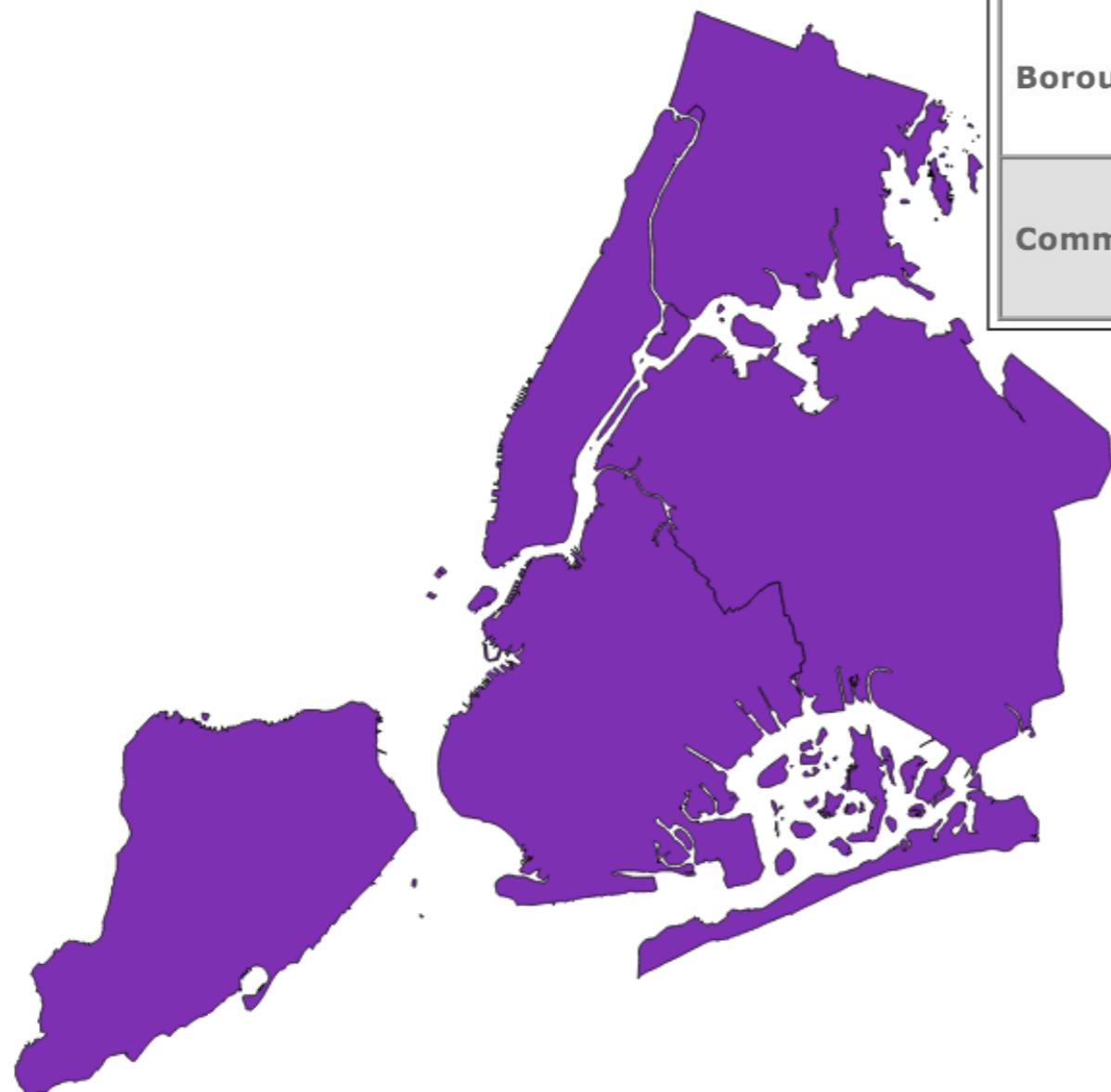
- Open specification developed by ESRI, still the current leader in commercial GIS software
- shapefiles aren't actual (individual) files...
- but actually a set of files sharing the same name but with different extensions:

```
(py35) (master) bgoncalves@underdark:$ls -l
total 4856
-rw-r--r--@ 1 bgoncalves  staff      537 Apr 17 12:40 nybb.dbf
-rw-r--r--@ 1 bgoncalves  staff      562 Apr 17 12:40 nybb.prj
-rw-r--r--@ 1 bgoncalves  staff  1217376 Apr 17 12:40 nybb.shp
-rw-r--r--@ 1 bgoncalves  staff   12905 Apr 17 12:40 nybb.shp.xml
-rw-r--r--@ 1 bgoncalves  staff     140 Apr 17 12:40 nybb.shx
-rw-r--r--  1 bgoncalves  staff      536 Apr 17 12:40 nybb_wgs84.dbf
-rw-r--r--  1 bgoncalves  staff     143 Apr 17 12:40 nybb_wgs84.prj
-rw-r--r--  1 bgoncalves  staff     257 Apr 17 12:40 nybb_wgs84.qpj
-rw-r--r--  1 bgoncalves  staff  1217376 Apr 17 12:40 nybb_wgs84.shp
-rw-r--r--  1 bgoncalves  staff     140 Apr 17 12:40 nybb_wgs84.shx
(py35) (master) bgoncalves@underdark:$
```

- the actual set of files changes depending on the contents, but three files are usually present:
 - **.shp** - also commonly referred to as "the" shapefile. Contains the geometric information
 - **.dbf** - a simple database containing the feature attribute table.
 - **.shx** - a spatial index, not strictly required

Shapefiles

http://www.nyc.gov/html/dcp/html/bytes/districts_download_metadata.shtml#bcd

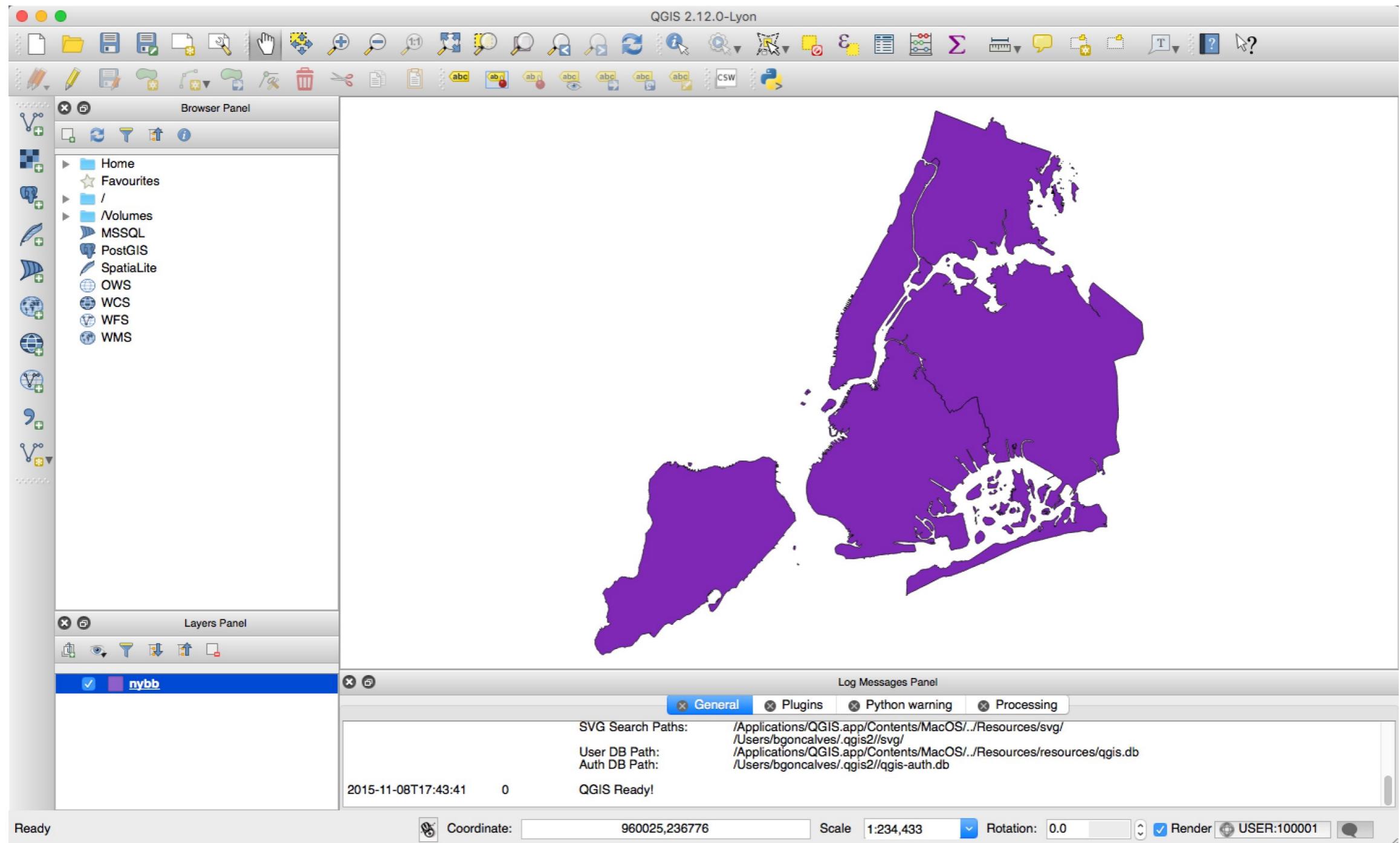


Borough Boundaries & Community Districts	Download	Metadata
Borough Boundaries (Clipped to Shoreline)	(645k)	
Borough Boundaries (Water Areas Included)	(31k)	
Community Districts (Clipped to Shoreline)	(772k)	

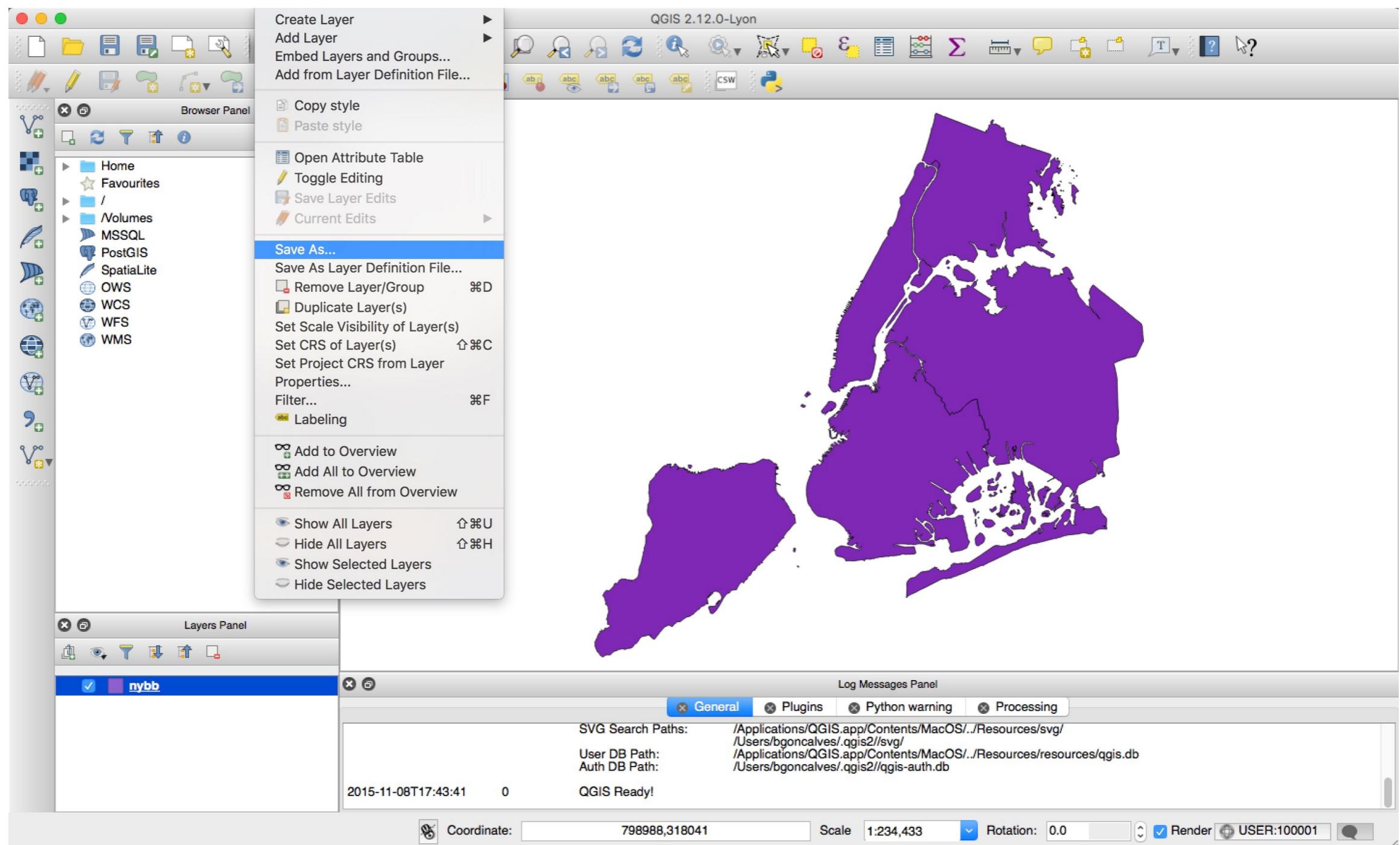
- Unfortunately it doesn't use the right reference system ([WGS84](#)), so we must convert it.



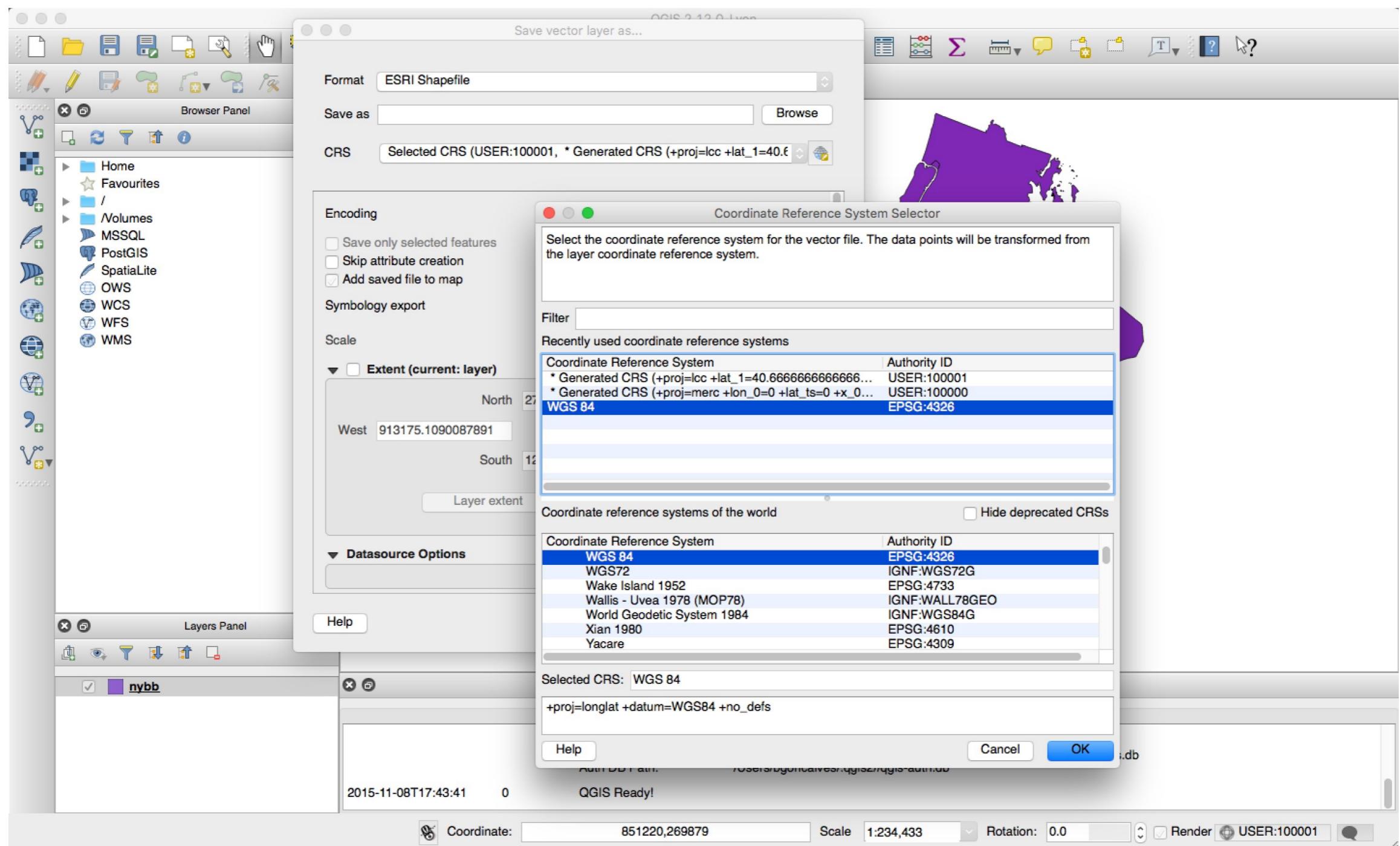
Shapefiles



Shapefiles



Shapefiles



pyshp

<https://github.com/GeospatialPython/pyshp>

- **pyshp** defines utility functions to load and manipulate Shapefiles programmatically.
- The **shapefile** module handles the most common operations:
 - **.Reader(filename)** - Returns a **Reader** object
 - **Reader.records()/Reader.iterRecords()** returns/iterates over the different records present in the shapefile
 - **Reader.shapes()/Reader.iterShapes()** - returns/iterates over the different shapes present in the shapefile
 - **Reader.shapeRecords()/Reader.iterShapeRecords()** returns/iterates over both shapes and records present in the shapefile
 - **Reader.record(index)/Reader.shape(index)/Reader.shapeRecord(index)** - return the record/shape/shapeRecord at index position **index**
 - **Reader.numRecords** - returns the number of records in the shapefile

pyshp

<https://github.com/GeospatialPython/pyshp>

```
import sys
import shapefile

shp = shapefile.Reader('geofiles/nybb_15c/nybb_wgs84.shp')

print("Found", shp.numRecords, "records:")

recordDict = dict(zip([record[1] for record in shp.iterRecords()], range(shp.numRecords)))

for record, id in recordDict.items():
    print(id, record)
```

@bgoncalves

shapefile_load.py

pyshp

<https://github.com/GeospatialPython/pyshp>
<http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf>

- **shape** objects contain several fields:

- **bbox** - lower left and upper right **x,y** coordinates (long/lat) - **optional**
- **parts** - list of indexes for the first point of each of the parts making up the shape.
- **points** - **x,y** coordinates for each point in the shape.

- **shapeType** - integer representing the shape type - all shapes in a shapefile are required to be of the same **shapeType** or **null**.

Value	Shape Type
0	Null Shape
1	Point
3	PolyLine
5	Polygon
8	MultiPoint
11	PointZ
13	PolyLineZ
15	PolygonZ
18	MultiPointZ
21	PointM
23	PolyLineM
25	PolygonM
28	MultiPointM
31	MultiPatch

Challenge - `pyshp`

- Write a simple script to plot out all the shapes in:

`geofiles/nybb_15c/nybb_wgs84.shp`

Challenge - pyshp

- Write a simple script to plot out all the shapes in:

geofiles/nybb_15c/nybb_wgs84.shp

```
import shapefile
import matplotlib.pyplot as plt
import numpy as np

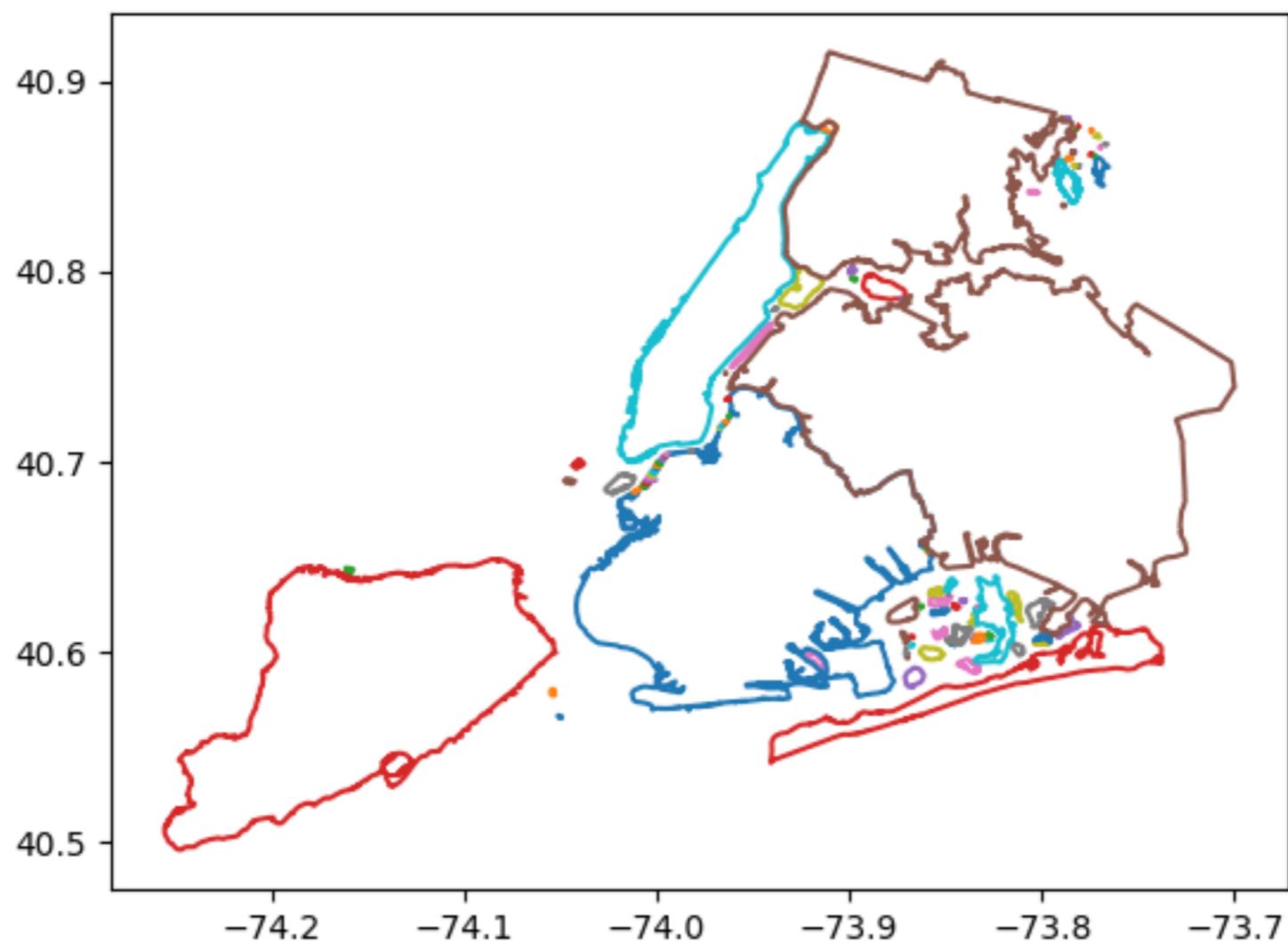
shp = shapefile.Reader('geofiles/nybb_15c/nybb_wgs84.shp')

pos = None
count = 0
for shape in shp.iterShapes():
    points = np.array(shape.points)
    parts = shape.parts
    parts.append(len(shape.points))

    for i in range(len(parts)-1):
        plt.plot(points.T[0][parts[i]:parts[i+1]], points.T[1][parts[i]:parts[i+1]])

plt.savefig('NYC.png')
```

Challenge - pyshp



shapely

<http://toblerity.org/shapely/manual.html>

- Shapely defines geometric objects under `shapely.geometry`:
 - `Point`
 - `Polygon`
 - `MultiPolygon`
 - `shape()` Convenience function that creates the appropriate geometric object

shapely

<http://toblerity.org/shapely/manual.html>

- Shapely defines geometric objects under `shapely.geometry`:
 - `Point`
 - `Polygon`
 - `MultiPolygon`
 - `shape()` Convenience function that creates the appropriate geometric object
- and common operations
 - `.crosses(shape)` - if it partially overlaps `shape`
 - `.contains(shape)` - whether it contains or not the object `shape`
 - `.within(shape)` - whether it is contained by object `shape`
 - `.touches(shape)` - if the boundaries of this object touch `shape`

shapely

<http://toblerity.org/shapely/manual.html>

- `shape` objects provide useful fields to query a shapes properties:
 - `.centroid` - The centroid ("center of mass") of the object
 - `.area` - returns the area of the object
 - `.bounds` - the MBR of the shape in (`minx`, `miny`, `maxx`, `maxy`) format
 - `.length` - the length of the shape
 - `.geom_type` - the Geometry Type of the object
- `shapely.shape` is also able to easily load `pyshp`'s shape objects to allow for further manipulations.

shapely

<http://toblerity.org/shapely/manual.html>

```
import sys
import shapefile
from shapely.geometry import shape

shp = shapefile.Reader('geofiles/nybb_15c/nybb_wgs84.shp')

recordDict = dict(zip([record[1] for record in shp.iterRecords()], range(shp.numRecords)))

manhattan = shape(shp.shape(recordDict["Manhattan"]))

print("Centroid:", manhattan.centroid)
print("Bounding box:", manhattan.bounds)
print("Geometry type:", manhattan.geom_type)
print("Length:", manhattan.length)
```

Challenge - Filter points within a Shapefile

- Load each tweet in **NYC.json.gz** file by using:

```
tweet = eval(line.strip())
```

- on each line and write to **Manhattan.json.gz** all the tweets within Manhattan, as defined by
geofiles/nybb_15c/nybb_wgs84.shp

Challenge - Filter points within a Shapefile

- Load each tweet in **NYC.json.gz** file by using:

```
tweet = eval(line.strip())

import sys
import shapefile
from shapely.geometry import shape, Point
import gzip

shp = shapefile.Reader('geofiles/nybb_15c/nybb_wgs84.shp')

recordDict = dict(zip([record[1] for record in shp.iterRecords()], range(shp.numRecords)))

manhattan = shape(shp.shape(recordDict["Manhattan"]))

fp = gzip.open("Manhattan.json.gz", "w")

for line in gzip.open("NYC.json.gz"):
    try:
        tweet = eval(line.strip())

        if "coordinates" in tweet and tweet["coordinates"] is not None:
            point = Point(tweet["coordinates"]["coordinates"])

            if manhattan.contains(point):
                fp.write(line)

    except:
        pass

fp.close()
```

Challenge - Filter points within a Shapefile

