Map Visualization for earthquakes throughout the world using Leaflet
Group 5
DSBA 5122: Visual Analytics
Final Report

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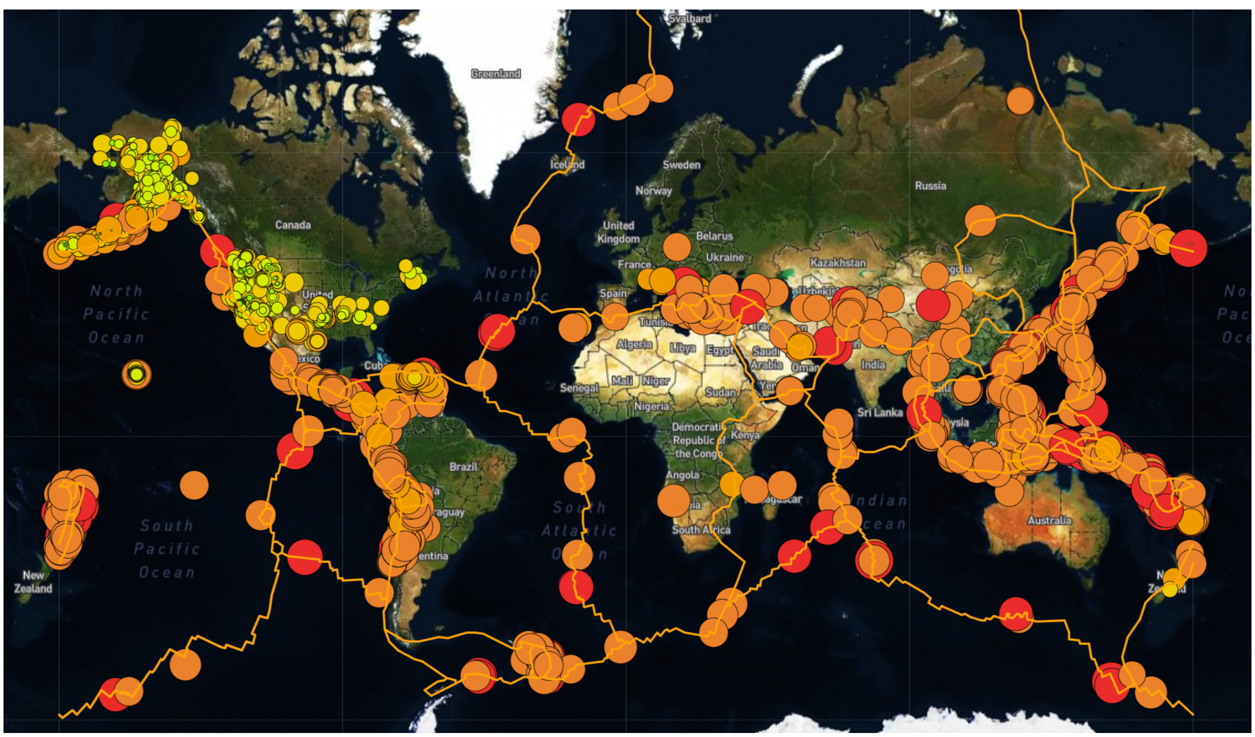


[Figure 1]

1. Introduction:

Data and information visualization is an interdisciplinary field that deals with the graphic representation of data and information. It is a particularly efficient way of communicating when the data or information is numerous as for example a time series.

It is also the study of visual representation of abstract data to reinforce human cognition. The abstract data include both numerical and non-numerical data, such as text and geographic information. It is related to infographics and scientific visualization. One distinction is that it's information visualization when the spatial representation (e.g., the page layout of a graphic design) is chosen, whereas it's scientific visualization when the spatial representation is given.

In the world of Big Data, data visualization tools and technologies are essential to analyze massive amounts of information and make data-driven decisions.

By using visual elements like charts, graphs, and maps, data visualization tools provide an accessible way to see and understand trends, outliers, and patterns in data.

1.1 Map Visualization:

Map visualization is used to analyze and display the geographically related data and present it in the form of maps. This kind of data expression is clearer and more intuitive. We can visually see the distribution or proportion of data in each region. It is convenient for everyone to mine deeper information and make better decisions.

There are many types in map visualization, such as administrative maps, heatmaps, statistical maps, trajectory maps, bubble maps, etc. And maps can be divided into 2D maps, 3D maps or static maps, dynamic maps, interactive maps, etc. They are often used in combination with points, lines, bubbles, and more.

In addition to the high efficiency of transmitting information, there is another important reason, that is, aesthetics. No matter how boring the content is, as long as it is equipped with a cool map, it will be eye-catching.

1.2 Leaflet:

Leaflet [1] is a JavaScript library that can be used to create online mapping applications.
It has all the mapping features most developers ever need. Here we create a map in the 'map' div, add tiles of our choice, and then add a marker with some text in a popup:

It is a great library for implementing interactive web maps as it provides many UI features, like smooth canvas panning, zooming, mouse events, and all the involved work in animations, which one would otherwise have to implement from scratch.
Leaflet is used to build web mapping applications.

Leaflet makes it simple for developers without a GIS experience to show title web apps hosted on a public server, along with configurable tiled overlays. It can import feature data from GeoJSON files, design it, and generate interactive layers like markers that open popups when clicked.

2. Data:

The United States Geological Survey, abbreviated USGS and formerly simply known as the Geological Survey, is a scientific agency of the United States government. We have taken our data from United States Geological Survey (USGS) that contains data from 1960 to 2020[5].

Our data[6] from USGS has many features but we limited ourselves to the below set of features that we thought were important to generate a map visualization of earthquakes that have occurred worldwide.

- **Magnitude (Decimal):** The magnitude reported is that which the U.S. Geological Survey considers official for this earthquake, and was the best available estimate of the earthquake's size
- **Place (String):** Textual description of named geographic region near to the event.
- **Time (Integer):** Time when the event occurred. Times are reported in *milliseconds* since the epoch (1970-01-01T00:00:00:000z), and do not include leap seconds. In certain output formats, the date is formatted for readability.
- **Timezone (Integer):** Timezone offset from UTC in minutes at the event epicenter.
- **url (String):** Link to USGS Event Page for details about the earthquake.
- **Alert (String):** The alert level from the PAGER earthquake impact scale.
- **Status (String):** Status is either automatic or reviewed. Automatic events are directly posted by automatic processing systems and have not been verified or altered by a human.
- **Tsunami (Integer):** This flag is set to "1" for large events in oceanic regions and "0" otherwise. The existence or value of this flag does not indicate if a tsunami actually did or will exist.
- **Signal (Integer):** A number describing how significant the event is. Larger numbers indicate a more significant event. This value is determined on a number

of factors, including magnitude, maximum MMI, felt reports, and estimated impact.

- **MagError (Decimal):** Uncertainty of reported magnitude of the event. The estimated standard error of the magnitude. The uncertainty corresponds to the specific magnitude type being reported and does not consider magnitude variations and biases between different magnitude scales.
- **MagNst (Integer):** The total number of seismic stations used to calculate the magnitude for this earthquake.
- **mmi (Decimal):** The maximum estimated instrumental intensity for the event. While typically reported as a roman numeral, for the purposes of this API, intensity is expected as the **decimal** equivalent of the roman numeral.
- **Network (String):** The ID of a data contributor. Identifies the network considered to be the preferred source of information for this event.
- **nph (String):** Number of P and S arrival-time observations used to compute the hypocenter location. Increased numbers of arrival-time observations generally result in improved earthquake locations.
- **rms (Decimal):** The root-mean-square (RMS) travel time residual, in sec, using all weights. This parameter provides a measure of the fit of the observed arrival times to the predicted arrival times for this location.
- **Depth (Decimal):** The depth where the earthquake begins to rupture. This depth may be relative to the WGS84 geoid, mean sea-level, or the average elevation of the seismic stations which provided arrival-time data for the earthquake location.
- **dmin (Decimal):** Horizontal distance from the epicenter to the nearest station (in degrees). 1 degree is approximately 111.2 kilometers. In general, the smaller this number, the more reliable is the calculated depth of the earthquake.
- **Gap (Decimal):** The largest azimuthal gap between azimuthally adjacent stations (in degrees). In general, the smaller this number, the more reliable is the calculated horizontal position of the earthquake.

2.1 <u>Data Picture:</u>

{"type":"FeatureCollection","metadata":{"generated":1652030262000,"url":"https://earthquake.usgs.gov/earthquakes/feed/v1.0/summary/all_month.geojson","title":"USGS All Earthquakes, Past Month","status":200,"api":"1.10.3","count":9228},"features":[{"type":"Feature","properties":{"mag":1.3,"place":"54 km SSW of Cantwell, Alaska","time":1652029815909,"updated":1652030014364,"tz":null,"url":"https://earthquake.usgs.gov/earthquakes/eventpage/ak0225vyyyvq","detail":"https://earthquake.usgs.gov/earthquakes/feed/v1.0/detail/ak0225vyyyvq.geojson","felt":null,"cdi":null,"mmi":null,"alert":null,"status":"automatic","tsunami":0,"sig":26,"net":"ak","code":"0225vyyyvq","ids":",ak0225vyyyvq,","sources":",ak,","types":",origin,phase-data,","nst":null,"dmin":null,"rms":0.66,"gap":null,"magType":"ml","type":"earthquake","title":"M 1.3 - 54 km SSW of Cantwell, Alaska"},"geometry":{"type":"Point","coordinates":[-149.4468,62.9613,80.1]},"id":"ak0225vyyyvq"},

[Figure 2]

{"type":"Feature","properties":{"mag":1.3,"place":"10km NNW of Anza, CA","time":1652027798940,"updated":1652028460070,"tz":null,"url":"https://earthquake.usgs.gov/earthquakes/eventpage/ci40254560","detail":"https://earthquake.usgs.gov/earthquakes/feed/v1.0/detail/ci40254560.geojson","felt":null,"cdi":null,"mmi":null,"alert":null,"status":"automatic","tsunami":0,"sig":26,"net":"ci","code":"40254560","ids":",ci40254560,","sources":",ci,","types":",focal-mechanism,nearby-cities,origin,phase-data,scitech-link,","nst":50,"dmin":0.06456,"rms":0.22,"gap":30,"magType":"ml","type":"earthquake","title":"M 1.3 - 10km NNW of Anza, CA"},"geometry":{"type":"Point","coordinates":[-116.7106667,33.6405,12.92]},"id":"ci40254560"},

[Figure 3]

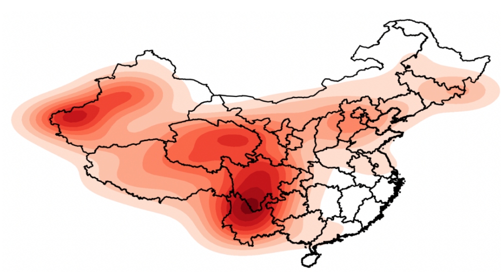
The figures above are some of the snippets from our data. These display all the features that we have considered. For example, here in the figure [2] and figure [3], we see the earthquake's type, mag, time, tz as in timezone, alert, tsunami, status, net as in network, etc.

3. Motivation:

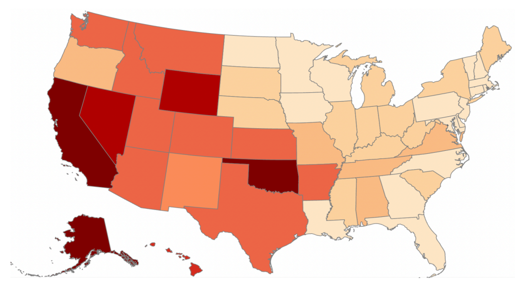
In certain circumstances, maps provide an effective and intuitive approach to comprehend data. Interactive online maps can assist us in better visualizing data and gaining new insights.

[Figure 4]

Various map representations may be used to emphasize various characteristics of a dataset. For this, heatmaps, choropleth maps, and clustering maps are widely employed.

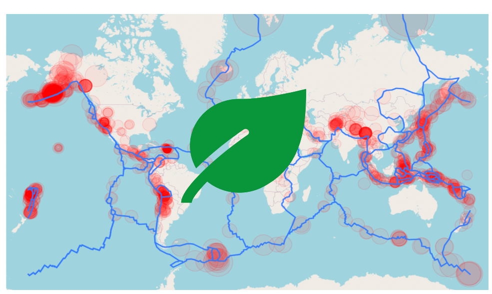


[Figure 5]



[Figure 6]

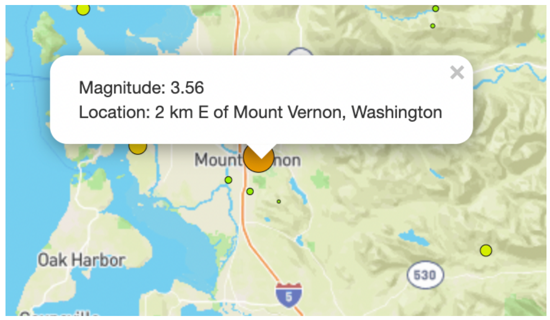
However, we created a map using the Leaflet JavaScript library.



[Figure 7]

4. Aim/ Method:

Our primary aim was to visualize earthquake data using leaflet which is an open-source JavaScript library.
As depicted in the figure [8] below, we can see that our leaflet displays the magnitude of the earthquake that has occurred and also the place where an earthquake occurred. This shows us that our leaflet is an interactive map.



[Figure 8]

Binding a Leaflet "map" element to an HTML element like a div is a common Leaflet use case. The map element is then embellished with layers and markings.

Leaflet and OpenLayers are both open-source JavaScript libraries that are solely used on the client side. In comparison to OpenLayers' 230,000 lines of code, the library as a whole is substantially smaller.

It's also analogous to the closed-source, proprietary Google Maps API (first released in 2005) and Bing Maps API, all of which have a large server-side component to enable services like geocoding, routing, search, and interaction with Google Earth.

5. Code:

Below are the snippets explaining the main features that we have added to our map using leaflet library, which is an open-source JavaScript library.

```
// Selectable backgrounds of our map - tile layers:
// grayscale background.
var graymap_background = L.tileLayer("https://api.mapbox.com/styles/v1/mapbox/light-v9/tiles/256/{z}/{x}/{y}?" +
  "access_token=pk.eyJ1IjoibWFudWVsYW1hY2hhZG8iLCJhIjoiY2ppczQ0NzBtMWNydTNrdDl6Z2JhdzZidSJ9.BFD3qzgAC2kMoEZirGaDjA");

// satellite background.
var satellitemap_background = L.tileLayer("https://api.mapbox.com/styles/v1/mapbox/satellite-streets-v9/tiles/256/{z}/{x}/{y}?" +
  "access_token=pk.eyJ1IjoibWFudWVsYW1hY2hhZG8iLCJhIjoiY2ppczQ0NzBtMWNydTNrdDl6Z2JhdzZidSJ9.BFD3qzgAC2kMoEZirGaDjA");

// outdoors background.
var outdoors_background = L.tileLayer("https://api.mapbox.com/styles/v1/mapbox/outdoors-v9/tiles/256/{z}/{x}/{y}?" +
  "access_token=pk.eyJ1IjoibWFudWVsYW1hY2hhZG8iLCJhIjoiY2ppczQ0NzBtMWNydTNrdDl6Z2JhdzZidSJ9.BFD3qzgAC2kMoEZirGaDjA");
```

[Figure 9]

Code in Figure [9] explains the way we selected backgrounds for our map. We have chosen maps with backgrounds greymap view, satellite view, and outdoors view.

```
// retrieve earthquake geoJSON data.
d3.json("https://earthquake.usgs.gov/earthquakes/feed/v1.0/summary/all_month.geojson", function(data) {
```

[Figure 10]

Code in Figure [10] depicts the way we retrieved earthquake GeoJSON data.

```
// add GeoJSON layer to the map
L.geoJson(data, {
  pointToLayer: function(feature, latlng) {
    return L.circleMarker(latlng);
  },
  style: styleInfo,
  onEachFeature: function(feature, layer) {
    layer.bindPopup("Magnitude: " + feature.properties.mag + "<br>Location: " + feature.properties.place);
  }

}).addTo(earthquakes);

earthquakes.addTo(map);
```

[Figure 11]

Code in Figure [11] shows the addition of GeoJSON layer to our map.

```
// retrive Tectonic Plate geoJSON data.
d3.json("https://raw.githubusercontent.com/fraxen/tectonicplates/master/GeoJSON/PB2002_boundaries.json",
  function(platedata) {

    L.geoJson(platedata, {
      color: "orange",
      weight: 2
    })
    .addTo(tectonicplates);

    // add the tectonicplates layer to the map.
    tectonicplates.addTo(map);
  });
```

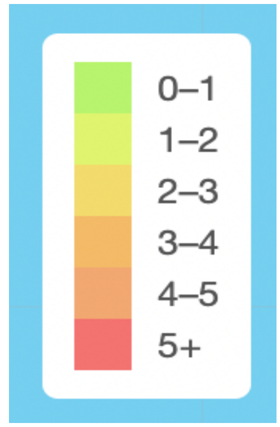
[Figure 12]

Code in Figure [12] displays the way we retrieved Tectonic plates to the GeoJSON data. A tectonic plate (also called as lithosphere plate) is a massive, irregularly shaped slab of solid rock, generally composed of both the continental and oceanic lithosphere. Plate size can vary greatly, from a few hundred to thousands of kilometers across.

Code in Figure [13] depicts the code we used to define the colors of the marker that were based on the magnitude of the earthquake that was occurred. We have defined the magnitude scale as seen in the figure [14]. Bigger the circle in the map, greater the impact of the earthquake. Also, higher the magnitude of the earthquake, higher the impact that would be felt. Overall, we can say magnitude of the earthquake is directly proportional to the impact of the same.

```
// Define the color of the marker based on the magnitude of the earthquake.
function getColor(magnitude) {
  switch (true) {
    case magnitude > 5:
      return "#ea2c2c";
    case magnitude > 4:
      return "#ea822c";
    case magnitude > 3:
      return "#ee9c00";
    case magnitude > 2:
      return "#eecc00";
    case magnitude > 1:
      return "#d4ee00";
    default:
      return "#98ee00";
  }
}
```

[Figure 13]

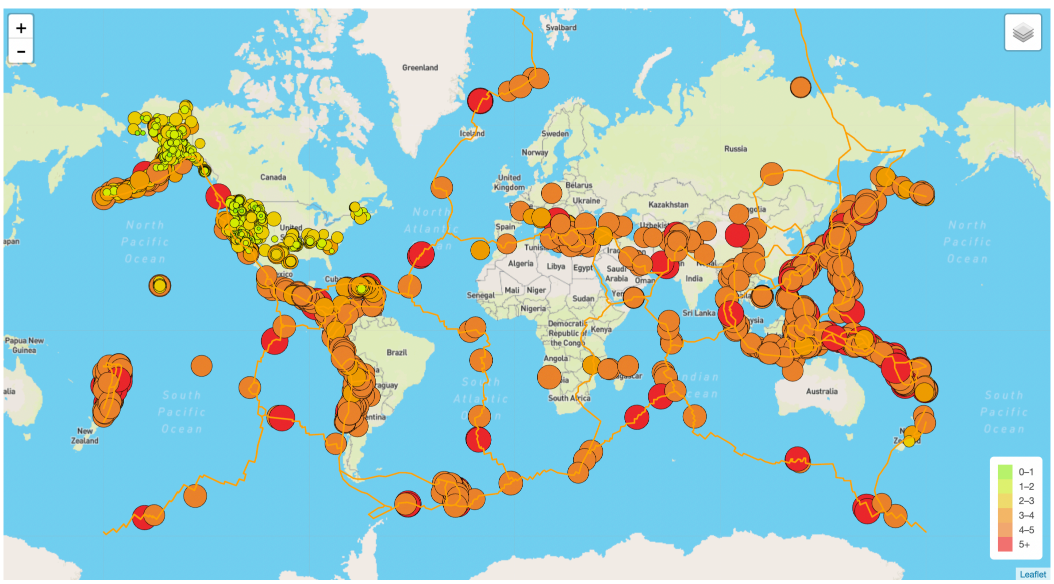


[Figure 14]

6. Results:

From the figure [15], we can see that the circle represents the impact, and the color represents the magnitude. It depicts the outdoor view.

Figure [15] also represents the earthquakes that have occurred worldwide. We also observe that most of the earthquakes worldwide have occurred in the coastal regions.



[Figure 15]

The orange line depicts the Tectonic plates. Figure [15] depicts the outdoor view of our map which we can select from options available from Figure [16], Figure [17], and Figure [18] that includes earthquakes occurred worldwide along with tectonic plates.
The link to our interactive map we generated using leaflet is
https://webpages.charlotte.edu/pveeram1/VisIndex.html
When you try opening our interactive map, you can do many operations on our map such as zoom in, zoom out, and select different backgrounds, etc.

We can zoom into and onto the map either by using the mousepad or by clicking the icons located on the left corner of the page displayed by “+” and “-” as shown in Figure [15].

The icon on the right corner has the layout i.e., the background for our map and also to choose between earthquakes or tectonic plates or both which can also be seen from Figure [15].

The icon towards your bottom left corner displays the magnitude chart. It has 5 different ranges and accordingly 5 different colors associated with each magnitude range. We can see the same in the map in Figure [15] and separately in Figure [14].

We have also added popups to our map where if you click on a particular earthquake, you get to see its magnitude and location as seen in Figure [8].

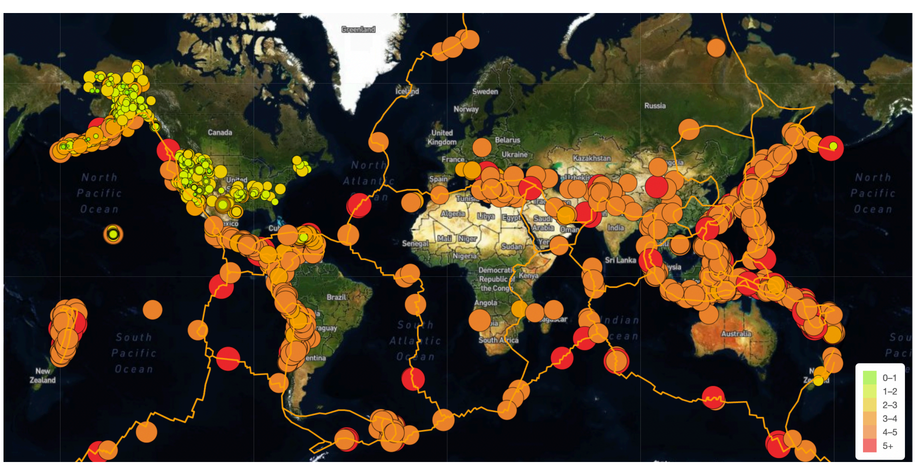
7. Observations/Insights learned from our map from data:

The following observations/ insights have been learnt from our map from data given by United States Geological Survey (USGS):

- The circum-Pacific belt is home to 80% of all earthquakes, the majority of which are triggered by convergent margin activity, according to the map we generated using leaflet.
- The Mediterranean-Asian belt accounts for 15% of all earthquakes, whereas plate interiors and spreading ridge centers account for the remaining 5%.
- Over 150,000 earthquakes significant enough to be felt are registered each year.

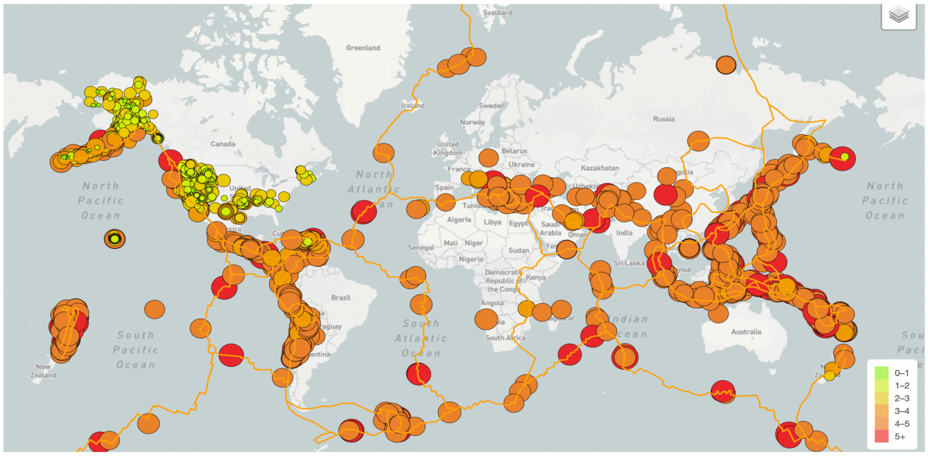
8. Different layouts available in our map:

We have generated our interactive map using leaflet with three different backgrounds/ layouts which are as follows.



[Figure 16]

Figure [16] depicts the satellite view of our map. It has all the earthquakes that have occurred worldwide along with tectonic plates.



[Figure 17]

Figure [17] depicts the greyscale view of our map. It also has all the earthquakes that have occurred worldwide along with tectonic plates.

[Figure 18]

Figure [18] depicts the outdoor view of our map. It has only the tectonic plates displayed.

9. Conclusion:

From the map we generated using leaflet, we can conclude that major earthquakes impacted the West Coast of the United States of America, Japan, and the Philippines, according to the visualization map we created using Leaflet.

We may also conclude that coastal regions are the most severely affected by earthquakes.

An earthquake's average magnitude is between 4 and 5, whereas mild earthquakes with magnitudes ranging from 0 to 2 hit the North American continent.

References:

[1] https://leafletjs.com/

[2] https://leafletjs.com/examples.html

[3] Class materials

[4] Previous assignments from the course DSBA 5122 Visual Analytics under Prof. Wenwen Dou.

[5] https://earthquake.usgs.gov/earthquakes/map/?extent=9.1021,-144.22852&extent=59.31077,-45.79102

[6] https://www.usgs.gov/programs/earthquake-hazards/earthquakes

[7] https://earthquake.usgs.gov/earthquakes/feed/v1.0/geojson.php

[8] https://scholar.google.se/scholar?cluster=1268723667321132798