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Foresight DRM

Disaster Risk Mapping Hackathon 2023

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Introduction

Globally, natural disasters have been a cause of major distractions in both human activities and lives. Statistically, it accounts for 0.1% of the total deaths in the world (Richie, 2022). They consist of phenomena such as hurricanes, floods, drought, earthquakes and landslides with each region of the earth experiencing one or more. The Caribbean countries, located in the, are extremely vulnerable to climate change and natural disasters (World Bank, 2023). Weather conditions in the region are often extreme which result in a lot of destruction.

Recent developments in the field of Geoinformatics have led to a renewed interest in mapping these disaster scenarios. Geospatial data has become more readily available due to the rise of free and open-source policies. In the context of this hackathon, we demonstrate the power of geospatial technologies in emergency response pre-, during and post- disaster in the Bahamas after Hurricane Dorian.

Main objective

The main objective for our solution for the hackathon is to demonstrate the impact of tropical cyclone on people living areas and to develop a user interactive tool for an emergency service

Data

Spatial data in the geospatial field ranges from vector (points, lines and polygons) and raster (Schneider, 2009). In our solution we integrated both datasets and are described as follows:

OSM data

Open Street Map (OSM) is a crowd-sourced map of the word designed for free usage under an open license (OSM, 2023). We used the platform to acquire buildings and roads data for the Grand Bahama Island through this link (https://overpass-turbo.eu/).

CEMS Vector Packages

Copernicus Emergency Management Service (CEMS) is a European funded organization that provides on-demand detailed information for selected emergency situations that arise from natural or man-made disasters anywhere in the world. In our application, we acquired the vector packages from the 2019 Hurricane Dorian activation (https://emergency.copernicus.eu/mapping/list-of-components/EMSR385/ALL/EMSR385_AOI03). The data from the vector package that we applied to our application was the flood mask for the Grand Bahama Island.

Climate Data Store time series data

We acquired time series data on sea level change (SLC) and sea surface temperature (SST) from the Climate Data Store (https://cds.climate.copernicus.eu/)

Ancillary data

We acquired additional data to help support our application. Hurricane data was obtained from NOAA (https://www.nhc.noaa.gov/gis/archive_forecast.php?year=2019) and shapefiles data showing the extent of the Bahamas main lands was obtained from University of Texas at Austin libraries (https://geodata.lib.utexas.edu/catalog/stanford-gr421mg4744).

Methodology

Our solution is a web application and this section is designed to describe the structure in which we implemented it. The app is powered by spatial data for emergency response efforts for Hurricane Dorian and is implemented in three phases. Each phase will have its specific objectives and deliverables, which will contribute to the overall success of the project. The three phases are as follows:

Phase 1

The objective of this phase was to simulate the tracking of the movement of Hurricane Dorian before it made landfall in the Grand Bahama Island. The dates we used for the simulation were as follows:

- August 24, 2019 (11 am, 5 pm and 11 pm),
- August 25, 2019 (8 am, 5pm and 11 pm) and
- August 26, 2019 (11 am, 5 pm and 11 pm)

To symbolize this, the data used here were points that represent the storm centers, lines that represent the hurricane tracks and the polygons that represent potential areas that the hurricane can hit. This data was overlaid together in ArcGIS online and symbolized using a graduated color scheme to actually illustrate the movement of the hurricane from August 24, 2019 to August 26, 2019.

The prediction date for the hurricane to reach the Grand Bahama on August 26, 2019 however it made landfall on September 1, 2019 illustrating a 5 days delay. By doing this phase the government may plan countermeasures for handling the upcoming impacts.

Phase 2

The objective of this phase was to design a user interactive interface for the emergency responders who are our stakeholders to assist in the rescue operations during the hurricane. To achieve this objective, we designed a real time vehicle routing system that will enable the responders to obtain the most optimal route to reach the victims. The interface is as follows:

- A leaflets base map to provide background detail necessary to orient the location of the map. Leaflets is an open-source JavaScript library used in the creation of interactive maps (https://leafletjs.com/).

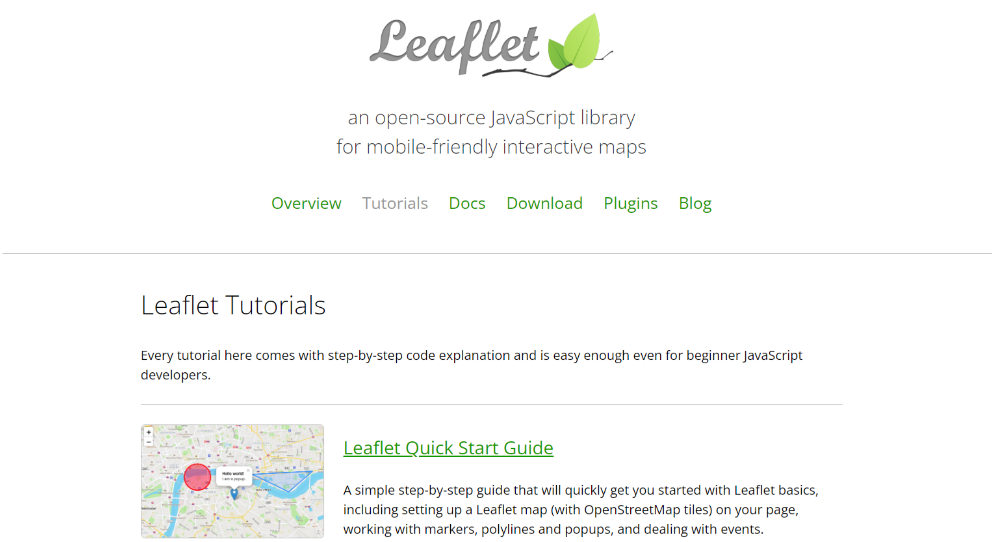

Figure 1: Leaflet documentation

The leaflet library was important to us because it enabled us to create an interactive front end for our web application based on JavaScript and React.

leaflet > src > components > pages > Effect > MapContent.js > MapContent > mapRef

```javascript
import React, { useRef, useState } from 'react'
import {MapContainer,LayersControl,LayerGroup} from 'react-leaflet'
import BaseMap from '../../BaseMap'
import 'bootstrap/dist/css/bootstrap.min.css';
// import WMSLayer from './layers/WMSLayer.js'
// import RoutingMachine from './layers/RoutingMachine';
import Boundary from './layers/Boundary';
import Flood from './layers/Flood';
import Density from './layers/Tiff';
import Building from './layers/Building';
import Road from './layers/Road';
import RoutingMachine from './layers/RoutingMachine';

const MapContent = () => {
    // javascript
    const mapRef = useRef()
    const [position, setPosition] = useState(null);

```

Figure 2: Code snippet used in designing the front end of our web app

- Then we connect and manage spatial data with GeoServer which is an open-source server that allows users to share, process and edit geospatial data. Then we connect and manage spatial data with GeoServer which is an open-source server that allows users to share, process and edit geospatial data.

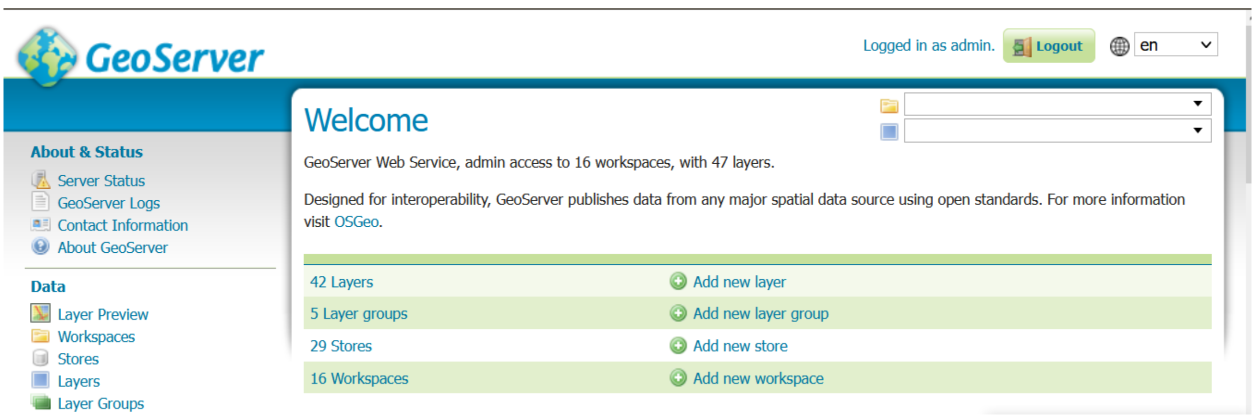

Figure 3: GeoServer graphical user interface

- Building density raster designed in ArcGIS Pro 3.0 from the OSM building footprints using the ‘kernel density tool’. We then overlay our building density raster layer on the leaflets base map together with the building polygon files to show the population density distribution in the Grand Bahama Island.

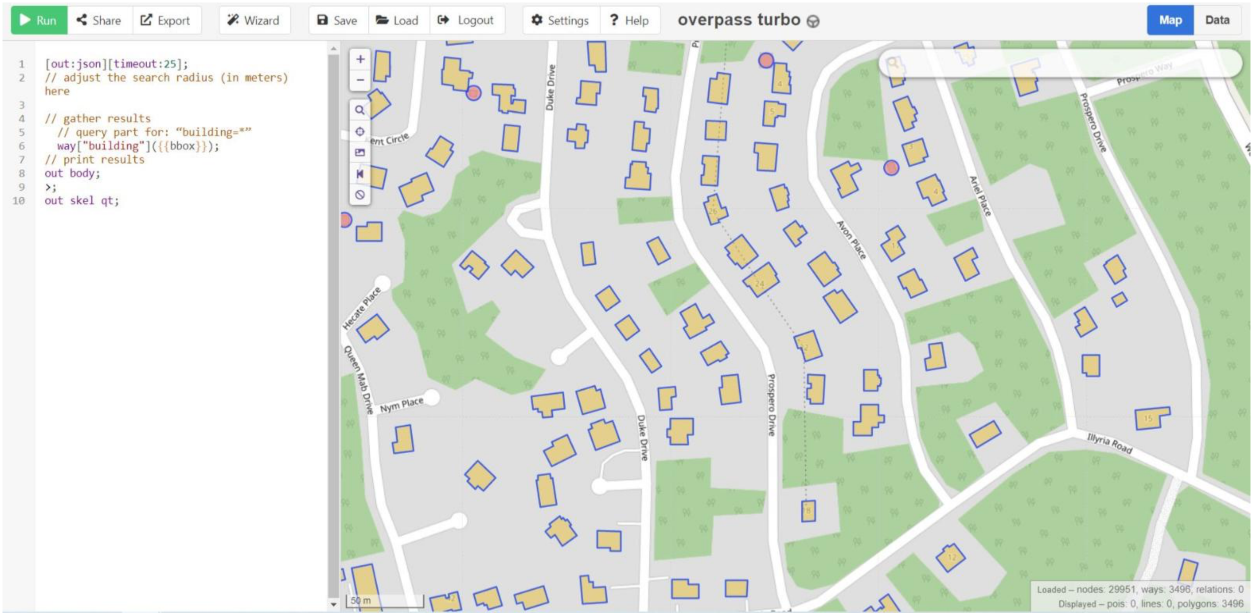

Figure 4: Building footprints queried from overpass turbo

- We overlay this with roads polylines that are useful for the routing demonstration.
- Moreover, we also consider the land cover classification in this area so we know which areas/land cover are prone to get the effect of floods. By doing this, we analyze by retrieving the data from Dynamic world, a 10 meter resolution near real time global land use land cover dataset in Google Earth Engine (https://developers.google.com/earth-engine/datasets/catalog/GOOGLE_DYNAMICWORLD_V1)

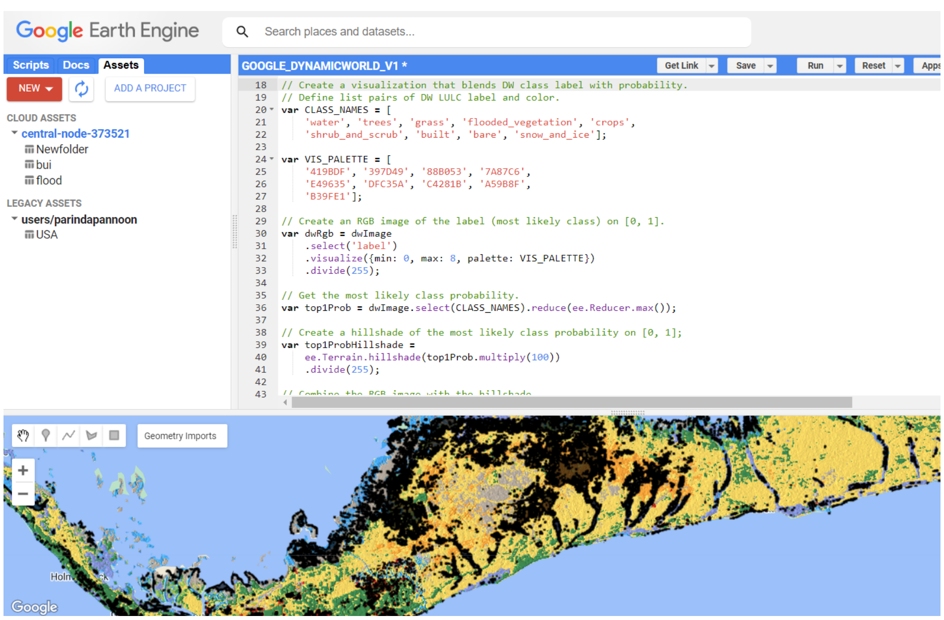

Figure 5: Overview of dynamic world cover in Google Earth Engine

In this phase, the emergency responders will be able to plan their routes in advance before deploying missions.

Phase 3

The objective of this phase was to predict the possible dates of hurricanes in future years and perhaps provide emergency responders with a heads up before disaster strikes. To achieve this objective, we utilized time series data from the Climate Data Store to predict sea level change in the Bahamas region.

The dataset used was the 'Global Sea level change indicators from 1950 to 2050 derived from reanalysis and high resolution CMIP6 climate projections' with a post-processing toolbox written in Python used to derive various statistics from the time series. The documentation indicates that indicators for tidal levels, extreme values, frequency distribution, and changes from the historical to future period are provided with actual values. Additionally, it highlights that ensemble statistics are provided, which are derived from the indicators of the five climate models.

The data was in NetCDF-4 format therefore we used a python script in Jupyter Notebooks to create a time series line graph from 2019 to 2030 in order to visualize the rate of change per year.

What does it do?

Pre–tracking

The pre-tracking site is an ArcGIS story map that we made public and embedded the link into our web application. Here (story map link), we can see the movement of the hurricane before hitting landfall in the Grand Bahama Island.

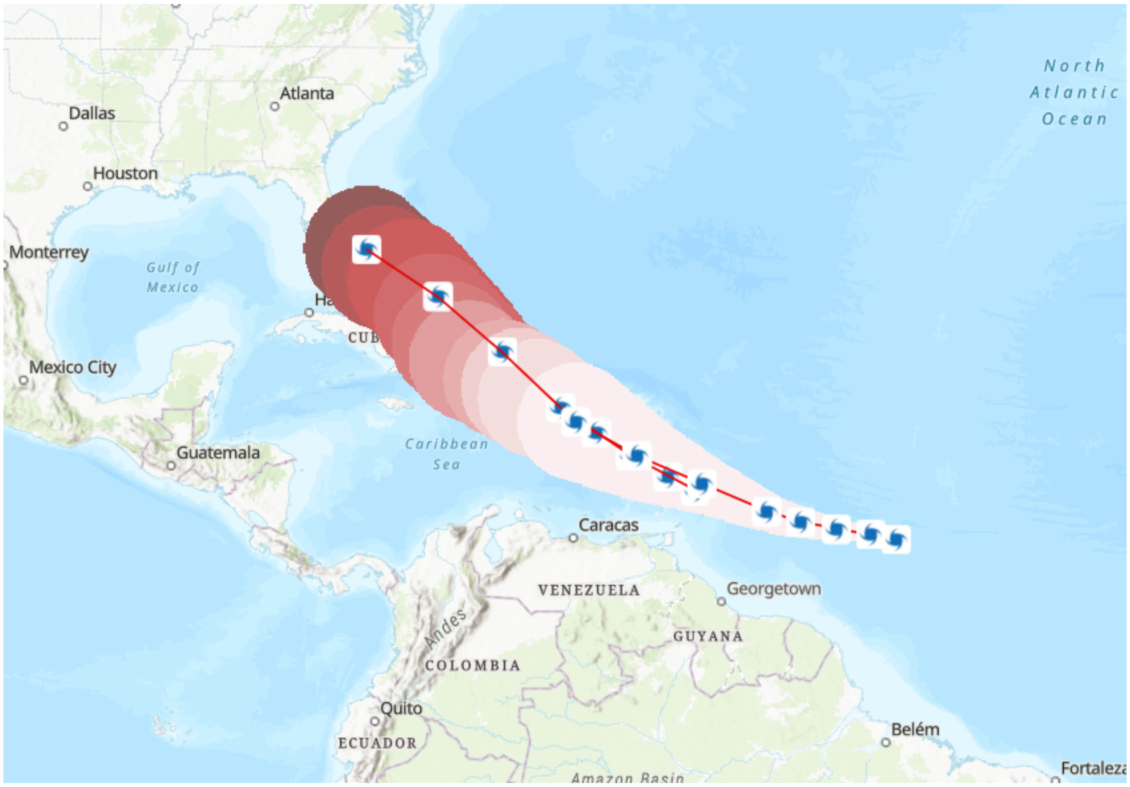

Figure 6: Hurricane movement

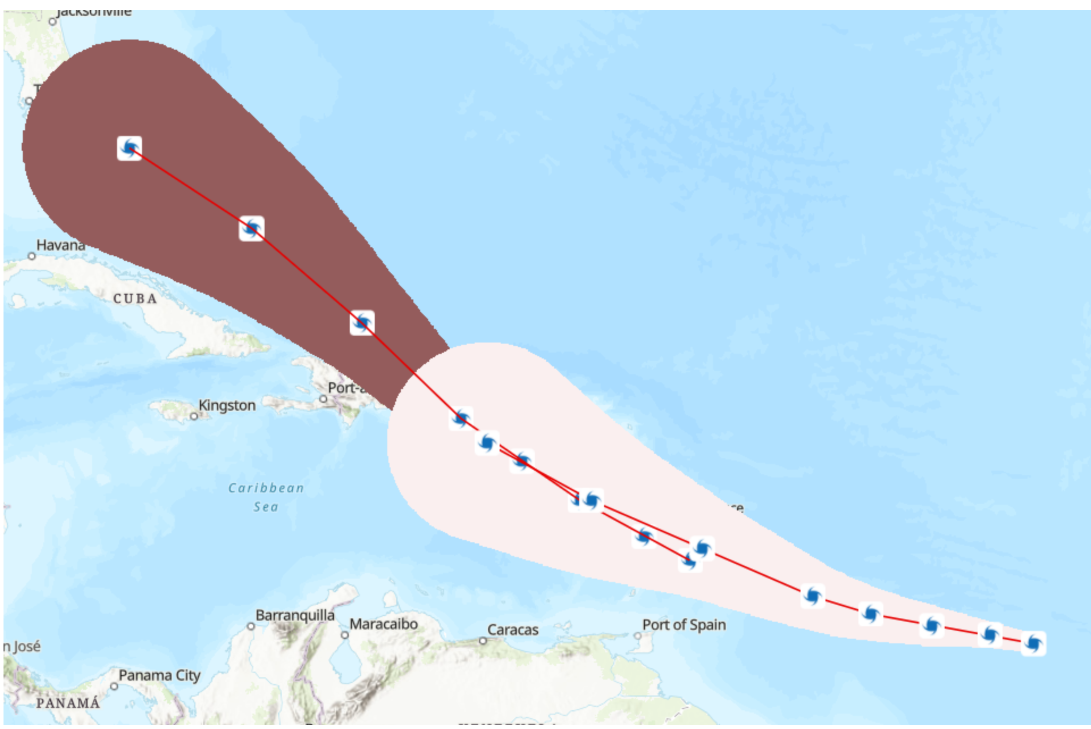

Figure 7: Hurricane Dorian landfall in the Grand Bahama Island

During–routing

The routing site is designed to provide the emergency responders with the most optimal route to reach victims during the hurricane. The screenshot below shows a sample illustration as to how responders from Calvary Temple in the Pineridge area can use our web app to request routing services to a distress call at the Eight Mile Rock residential area

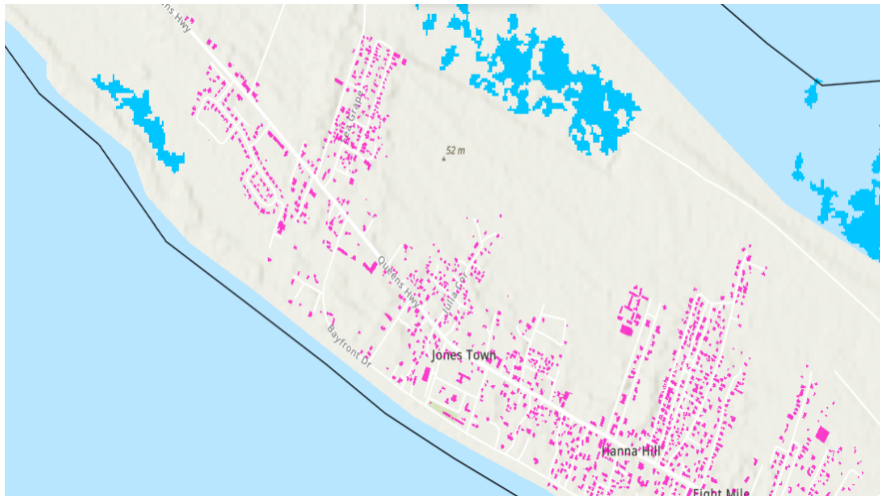

Figure 8: Flood prone areas

From the results, we can see that most of the flood areas are in the middle of the island, and the residential areas are located in the southwest of the island. However, there are some building areas around that are prone to get damaged by floods.

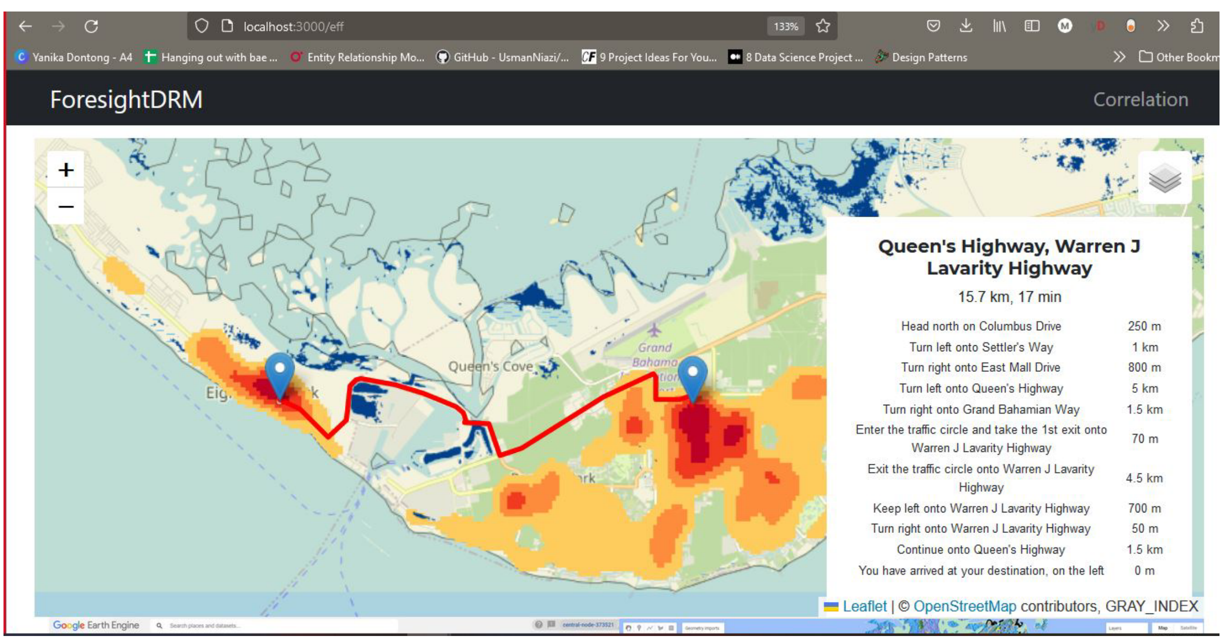

Figure 9: Web app simulation of routing request from Calvary Temple in the Pineridge area to the Eight Mile Rock residential area

In order to mitigate the flood-prone areas, we try to find a route that avoids the floods from this area to a shelter for evacuating people. This is a scenario that we select the area where has a high density of buildings and the destination is the shelter "Calvary Temple". Calvary temple is an official emergency shelter living area / 1.5 square meters.

The dynamic world land cover map from Google Earth Engine enables us to visualize the built-up areas, trees, water, grass, shrubs, snow and ice, flooded vegetation, grass and bare ground.

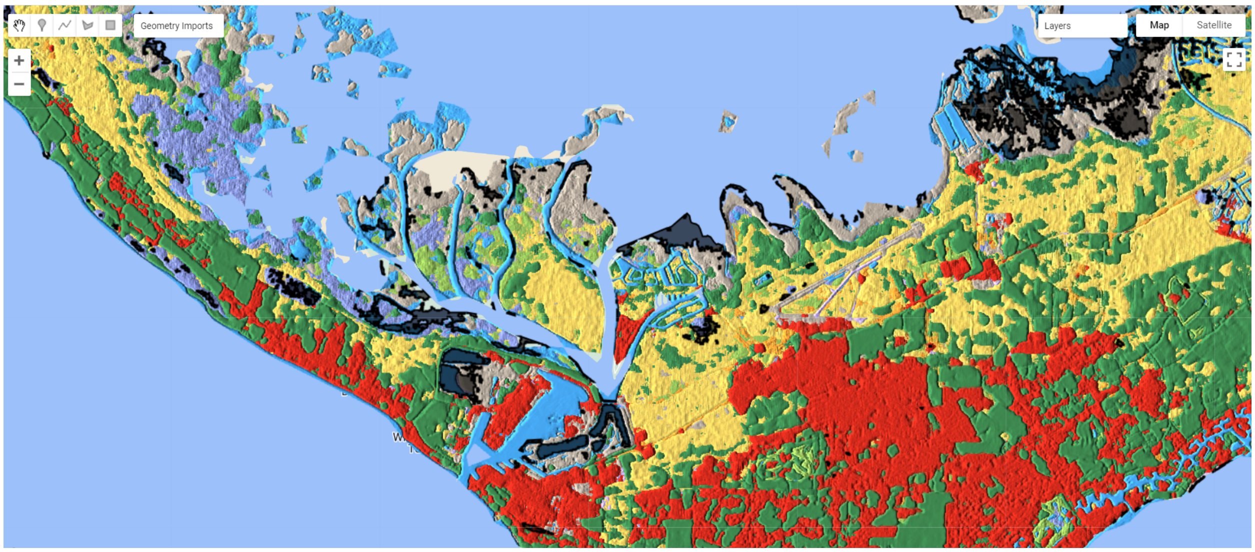

Figure 10: Overview of the dynamic world land cover for the Grand Bahama Island

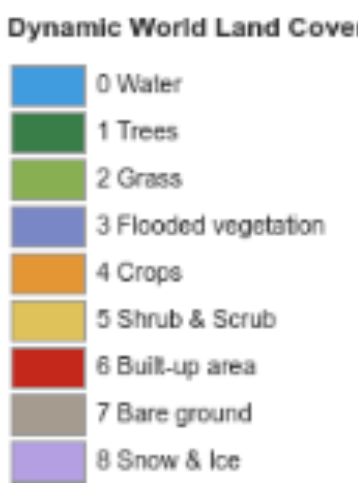

Figure 11: Legend of the dynamic world land cover

Let's discuss land use and land cover areas in the island. As you see the flood mask (Black extent) is spread over the middle of the island which is the area of shrubs (yellow) and crops(orange), so the vegetation areas tend to have the most impact from this disaster.

As we mentioned previously, the southwest areas are prone to be affected by floods and we can see that this area is surrounded by built-up areas and flooded vegetation(purple), therefore in this site may need some land use control or policies. For the future development may regulate land use and enforce building codes for areas vulnerable to the effects of tropical cyclones.

Post –graph prediction

The correlation site shows the simulation graph for the sea level change from 2019 to 2030. This is to act as a post-disaster simulation that would aid emergency responders

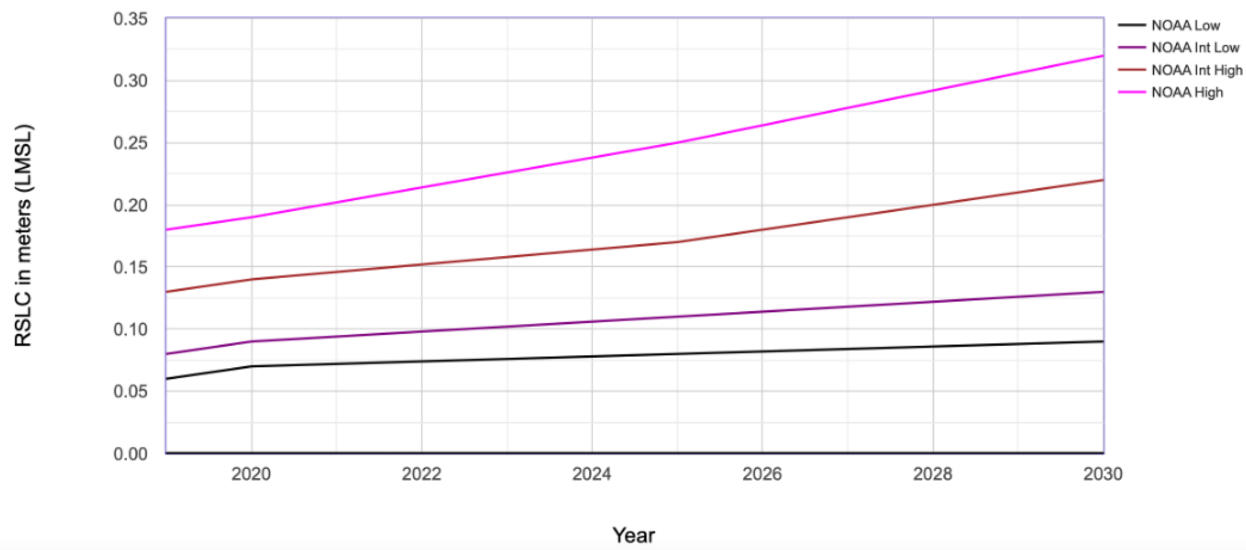

Figure 12: Sea level change (SLC) prediction from 2019 to 2030

Discussion

The whole web application was able to integrate well and seamlessly from phase 1 to phase 3. In the first phase, the focus is on tracking the movement of Hurricane Dorian. This involved collecting ancillary data to provide accurate information about the hurricane's location and trajectory. This information can be used to inform decision-making about evacuations, emergency preparedness, and other critical actions needed to protect the public.

In phase two, the focus is on designing an interactive interface for emergency responders to assist in rescue operations during the hurricane. It could also include tools for communicating with other responders, coordinating rescue efforts, and managing resources.

Finally, in phase three, the focus is on predicting future hurricanes and providing emergency responders with advanced warning before disaster strikes. This involved using data from past storms, weather patterns, and other sources to develop predictive models that can forecast the likelihood and timing of future hurricanes. This information can be used to inform emergency preparedness efforts, such as stockpiling supplies and mobilizing resources in advance of a storm's arrival.

Despite our accomplishments, the web application does not come without its challenges:

- Currently the web application runs on our local host thus cannot be accessed by the public.
- We used proprietary software (ArcGIS Online) to illustrate Phase 1 because due to time constraints that was the quickest way. However, the story map is public and is easily accessible from our web app as an embedded link.
- Phase 3 is the less interactive section in our application since the majority of our data is static.

Conclusion

Overall, the three-phase web application represents a comprehensive approach to hurricane tracking and response, providing critical information to stakeholders and potentially saving lives in the process. It demonstrates the power of technology and data in helping to mitigate the impacts of natural disasters and underscores the importance of proactive emergency preparedness efforts.

References

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