Northeastern University

Remote Sensing of the Environment
CIVE 5280

Final Project

Mapping Flooded Area and finding change in precipitation and total water storage anomaly in Harris County, Texas.

Ashis Kumar Pal

NU ID : 001553967

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Prof. R. Edward Beighley
Max Rome

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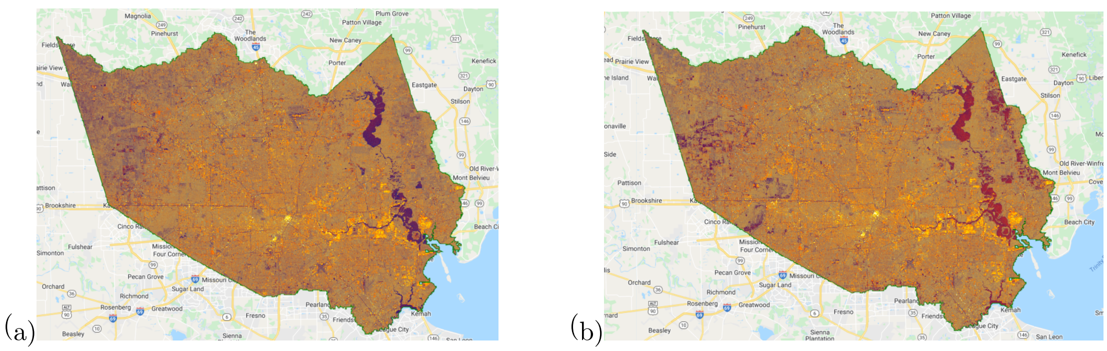
1 Introduction

Flooding is becoming more common, and this, along with expanding urbanization, is causing major economic losses due to structural and infrastructural damage. It is one of the most common hydrometeorological dangers, resulting in yearly financial losses of around $10 billion (USD). Without adaptation, average annual losses are expected to rise to more than $1 trillion by 2050. Similarly, projections from 2004 estimated that more over half a billion individuals were affected every year throughout the world, with that figure expected to treble by 2050. Climate change, population growth, and regional subsidence are all projected to worsen the problem, particularly in big coastal cities. As a result, it's vital that we enhance flood risk mapping, impact assessments, forecasting, alerting, and emergency response by better assessing the danger of flooding and quantifying the dynamics of water bodies throughout the world using improved remote sensing technology and analysis.

1.1 Study Area Description

My study area will be Harris county, Texas. Hurricane Harvey, a slow-moving Category 4 storm that hit the Houston, Texas, region on August 26, 2017 which caused flood. I will be calculating the flooded area using satellite data and then I will look into the monthly precipitation change and total water storage anomaly in Harris county.



(a) (b)

Figure 1: (a) Before (2017-07-10 to 2017-08-14) and (b) After (2017-08-18 to 2017-09-01) Flood image from Sentinel-1 SAR(Synthetic Aperture Radar) GRD(Ground Range Detected) VV/VH ratio band.

2 Data Sources

Flood Image: Imagery from the European Space Agency's (ESA) Sentinel-1A/B satellite (C-band SAR, IW(Interferometric Wide swath) mode) with a 6-12 day repeat period will be used. C-band SAR sensor has Spatial Resolution : 10m.

Precipitation: From CHIRPS. CHIRPS (Climate Hazards Group InfraRed Precipitation with Station Data) is a quasi-global rainfall dataset that spans 30 years. CHIRPS creates gridded rainfall time series using 0.05° resolution satellite images and in-situ station data for trend analysis and seasonal drought monitoring. Spatial Resolution : 5 km.

Permanent/Semi-permanent water bodies: From JRC GSW. (JRC Global Surface Water Mapping Layers, v1.3). This dataset contains maps of the location and temporal distribution of surface water from 1984 to 2020 and provides statistics on the extent and change of those water surfaces. These data were generated using 4,453,989 scenes from Landsat 5, 7, and 8 acquired between 16 March 1984 and 31 December 2020. Each pixel was individually classified into water / non-water using an expert system and the results were collated into a monthly history for the entire time period and two epochs (1984-1999, 2000-2020) for change detection. Spatial Resolution : 30 meters.

Steeper Terrain: From WWF HydroSHEDS. HydroSHEDS is a mapping product that provides hydrographic information for regional and global-scale applications in a consistent format. It offers a suite of geo-referenced datasets (vector and raster) at various scales, including river networks, watershed boundaries, drainage directions, and flow accumulations. HydroSHEDS is based on elevation data obtained in 2000 by NASA's Shuttle Radar Topography Mission (SRTM). This dataset is at 3 arc-second resolution. Spatial Resolution : 92.77 meters.

Total Water Storage Anomaly: From GRACE (Gravity Recovery & Climate Experiment) data. Launched in March 2002; ended Oct 2017. Orbit 500 km. Roughly 30-day revisits. It measures distance between two satellites. GRACE data are typically referenced as Total Water Storage Anomaly (TWSA). Represents difference in monthly water mass (i.e., gravity strength) relative to the water equivalent mean gravity field for period 2004 through 2009. We do not know total water storage; only changes relative to measurement period.

3 Methodologies

From Global Administrative Unit Layers (GAUL) of Food and Agriculture Organization(FAO) Harris county has been clipped from US map. Then using Sentinel-1A/B satellite data before flood and after flood image has been plotted for a easy comparison. But this after flood image has permanent and semi-permanent water bodies present and also there are steeper places where flood water can not clog. So, to remove this waters JRC Global Surface Water Mapping Layers 'seasonality' band has been used. If a place has water present for at least 5-6 months that place can be considered as a permanent water body/ reservoir/dam. Also using Hydrosheds DEM data, any terrain surface steeper than 8% has been masked out as flood water wouldn't accumulate there. After masking out these and using threshold difference between pixels flooded area has been calculated.
After that, from Climate Hazards Group InfraRed Precipitation with Station Data, precipitation and from GRACE , TWSA data has been collected to analyse water storage change and precipitation change in Harris county. Unfortunately, Grace data discontinued in 2017 so from 2002 to 2016 data has been accounted here.

4 Results

Total area of Harris county is 1771.37 square miles and flooded area came as 215.39 square miles. So, percent of area flooded in 2017 became :

$$\frac{215.39 \times 100}{1771.37} = 12.16\%$$

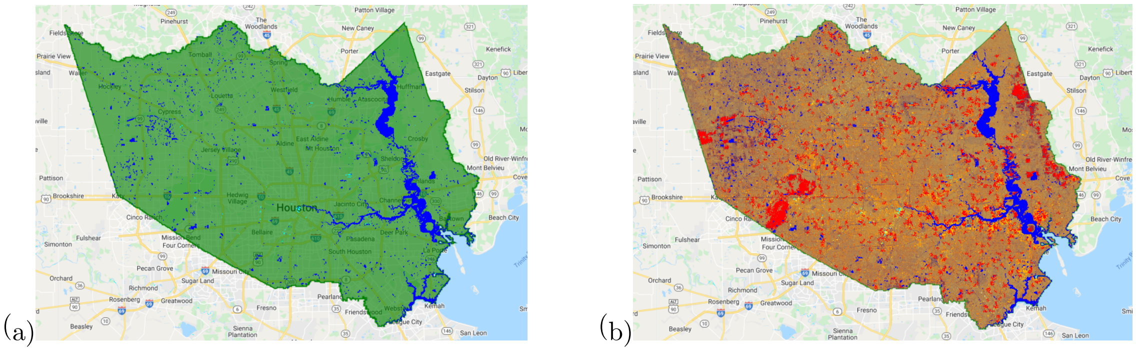


Figure 2: (a) Permanent water bodies(blue) from JRC Global Surface Water Mapping Layers, v1.3 and (b) Flooded area's(reddish) After masking out permanent water bodies and steeper(8% slope) places.

The flooded area's is shown in red pixels in Figure 2(b) after masking out permanent and semi-permanent water bodies. According to Wikipedia almost 400 square miles were flooded in Harris county which probably counted permanent water bodies as well.

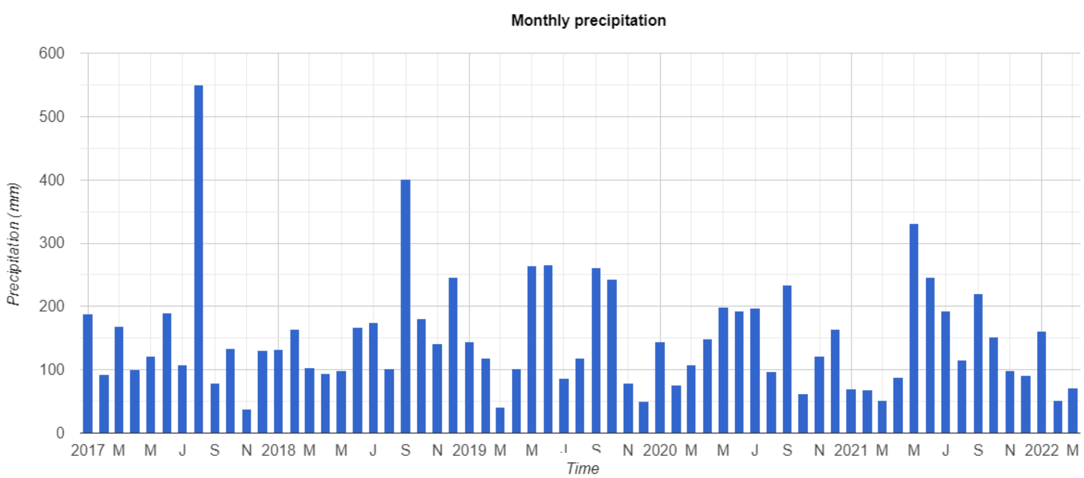


Figure 3: Monthly rainfall data for Harris county, Texas from CHIRPS.2017, Aug had maximum rainfall of 551 mm.

CHIRPS data shows how the rainfall differs from other months of the years. Figure 4 will show mean and maximum rainfall in the Harris county. As we have rainfall data and TWSA data, so next I wanted to explore if there is any co-relation between rainfall and water storage anomaly. If I find any strong co-relation, that could lead me calculate TWSA of 2017 since data is available up to 2016. The below Figure 5 shows a scatter plot between rainfall and TWSA of 2002-2016. A trend-line to fit the data was used but it ended up having $R^2 = 0.10$. Also co-relation value was 0.26 which doesn't yield a strong co-relation.

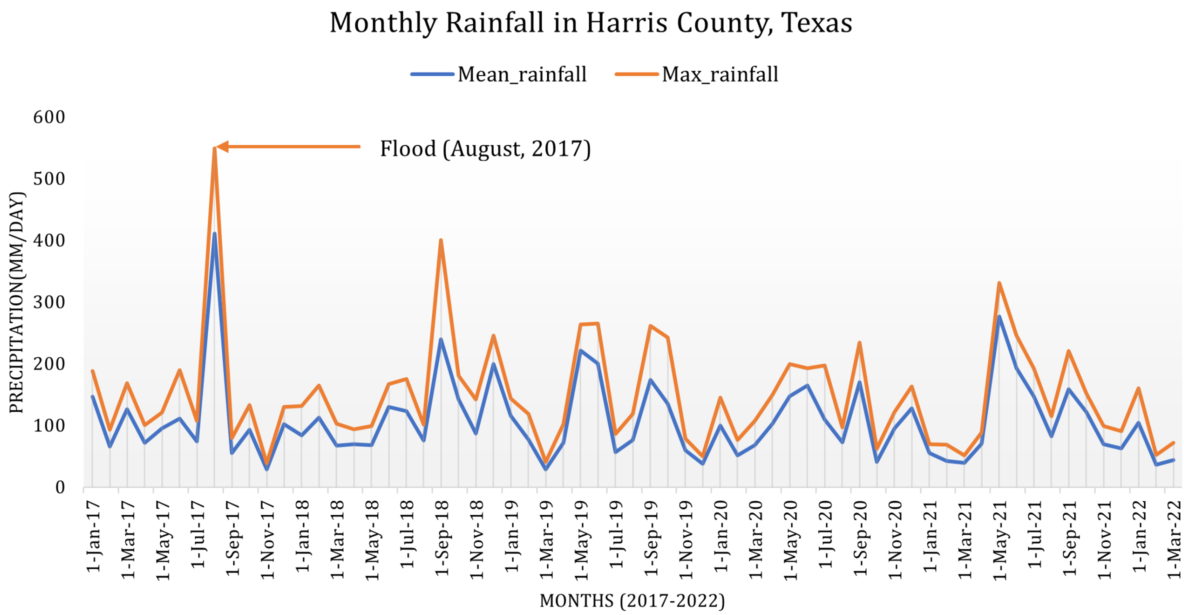


Figure 4: Monthly mean and maximum rainfall data for Harris county, Texas(2017-2022).

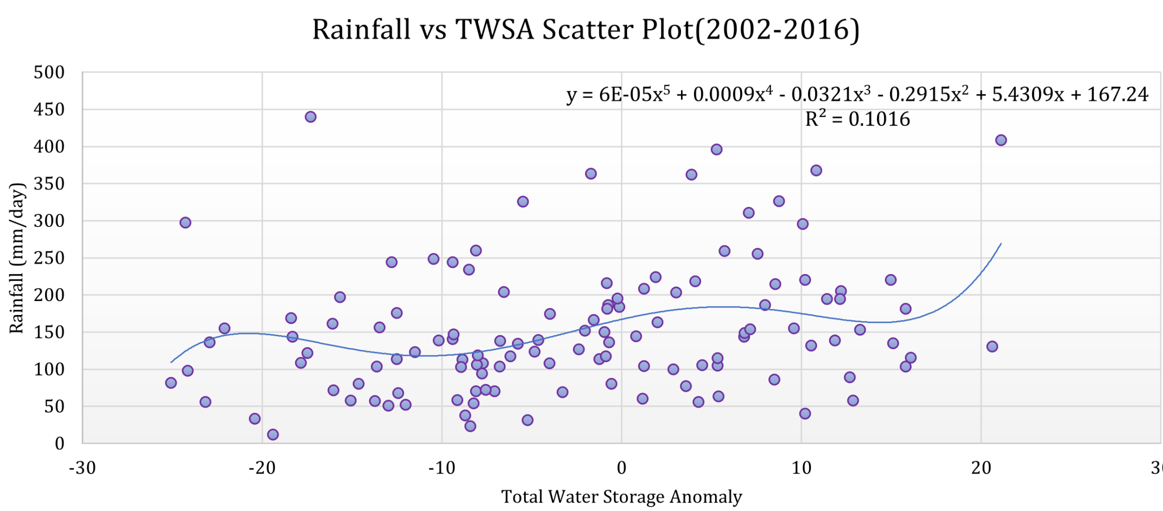


Figure 5: Scatter plot of Rainfall and TWSA (2002-2016) .

The overall water storage anomaly data from GRACE is depicted in the below Figure 6. From this Grace data , not much change is detected regarding the water storage change in my study site.

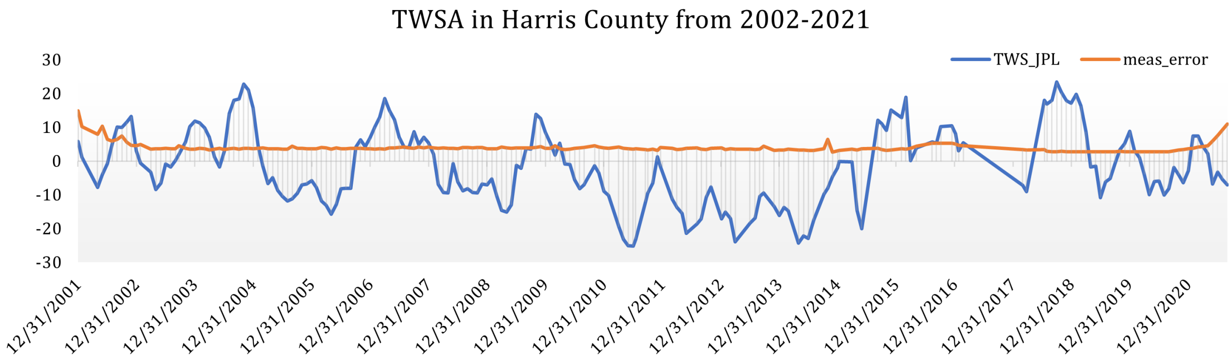


Figure 6: TWSA in Harris county, Texas during 2002 to 2021. Flood events detection wasn't possible as 2017 data wasn't found in GRACE data.

5 Conclusion

An approach for flooded area mapping using GEE has been used, utilizing Sentinel-1 SAR(Synthetic Aperture Radar) GRD(Ground Range Detected) data. As Sentinel-1 data doesn't differ due to cloud presence so it is convenient to use this satellite data. Finally, water storage anomaly and precipitation co-relation has been assessed to justify if there's any strong relation.

Google drive Link to All the files