New York City Flood Mapping Using Interferometric Wide-swatch Sentinel-1 SAR Imagery

HIRES Interns: Rishikesh Dasgupta[1], Tashfia Diha[1], Clare Hill[1], Saroni Sikder[1]
Graduate and Research Mentors: Yuneeb Awan[2], Ali Haider[3]
Faculty Advisors: Reza Khanbilvardi[3], Naresh Devineni[3]
[1]CUNY CREST High School Initiative in Remote Sensing of Earth System Engineering and Sciences (HIRES), The City College of New York, NY
[2]Earth and Atmospheric Sciences, The City College of New York, NY
[3]Department of Civil Engineering, CUNY-CREST Institute, and United Nations University (UNU) Hub on Remote-Sensing and Sustainable Innovations for Resilient Urban Systems (R-SIRUS)-UNU Institute for Water, Environment and Health (UNU-INWEH), The City College of New York, NY

Background/Motivations:

- Climate change, driven by human activity, worsens sea level rise in low-lying areas and increases severe weather, overwhelming urban sewage systems and causing flash floods [1].
- Flood mitigation is critical to protect vulnerable communities and regions.
- Flood susceptibility maps, enhanced by statistics or machine learning, are highly effective but require extensive historical flood data from in-situ (rain gauges) or remote sensing sources.

Theodore Parisienn/New York Daily News (July 16, 2023)

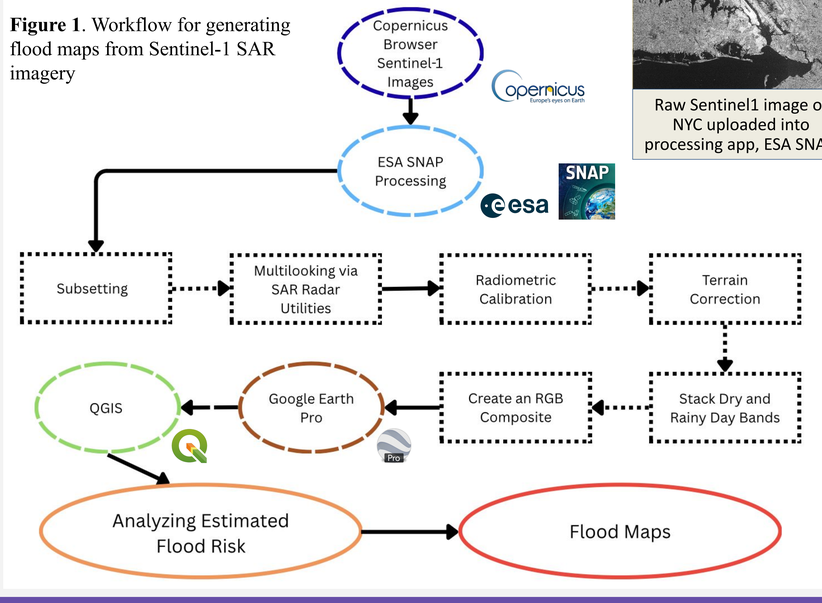
Research Objectives:

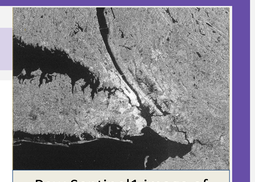
1. To learn how satellite remote sensing, especially Sentinel-1 radar data, can be used to observe flooded areas from space.
2. To visually analyze and compare Sentinel-1 images from rainfall and non-rainfall days in New York City.

Research Question:
How effective is Sentinel-1 satellite data usage in urban flooding analysis of New York City?

Methods:

Figure 1. Workflow for generating flood maps from Sentinel-1 SAR imagery





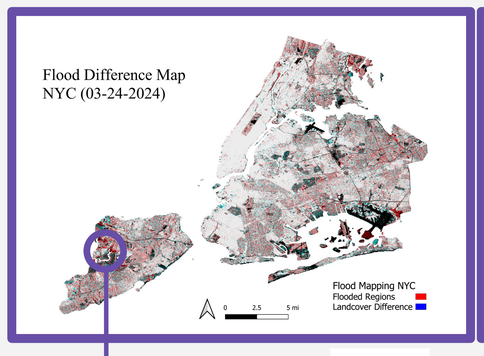
Raw Sentinel1 image of NYC uploaded into processing app, ESA SNAP.

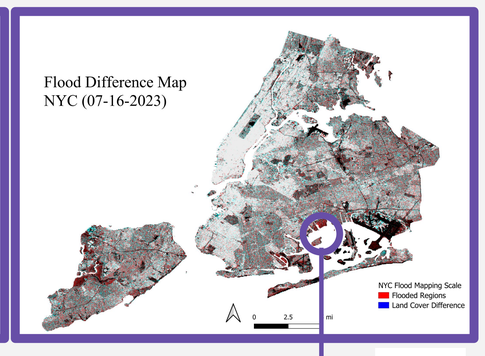
Study Area and Data:

- The study area was limited to New York City and its five boroughs (Brooklyn, Bronx, Manhattan, Queens, and Staten Island).
- The specific flood dates chosen were March 24, 2024, where there was **six inches of rain** intensity the day before and July 16, 2023, where there was **one to two inches of rain intensity**
- The satellite data was obtained through the ESA's Sentinel-1 IW processing mode from Copernicus Browser [6]. High-resolution precipitation data were sourced from the NYS Mesonet network (University at Albany), which uses tipping-bucket raingauges deployed throughout the state.

Results and Observations:

- Red indicates areas with a decrease in backscatter on the flooded day, consistent with *smooth water surfaces detected by SAR*. This decrease typically **represents surface water flooding.**
- Flooding is most intense in **low-elevation coastal zones** such as Howard Beach, Shirley Chisholm State Park, and Freshkills Park. These areas are prone to repeated flooding due to tidal influence, engineered drainage channels, and reduced natural absorption from impervious surfaces and lack of vegetation in NYC.
- In both events, **impervious urban surfaces and storm drainage systems** concentrated runoff into low elevated areas, amplifying flood extents beyond just rainfall.





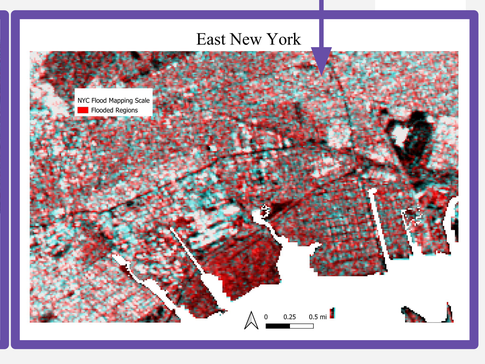


Figure 2. Flood detection for March 24, 2024, from Sentinel-1, 30 hours after the March 24, 2024, rain, likely under-representing floodwaters

Figure 3. Sentinel-1 image acquired 5 hours after rain event occurring on July 16, 2023

Results and Observations:

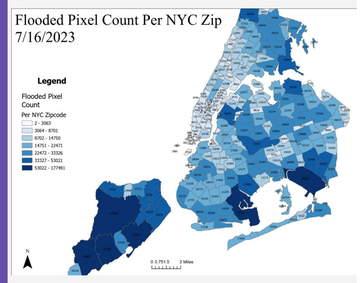


Figure 4. Flooded pixel counts per NYC ZIP code on July 16, 2023, derived from Sentinel-1 SAR flood difference imagery.

- **Staten Island** recorded the **highest flood pixel counts** in the city, with ZIP code 10314 showing 177,491 flooded pixels.
- In Queens, the **Jamaica Bay–Howard Beach area also exhibited intense flooding**, with ZIP code 11430 (adjacent to JFK Airport) registering 85,091 flooded pixels.

Discussions:

Validation of Results

- Flood signals in satellite images verified through news reports.
- March 24, 2024: Third wettest March day in NYC history.
- July 16, 2023: Heavy rainfall forecasted and addressed by NY Governor; major flooding in Brooklyn.

Data Collection Frequency

- Sentinel-1 revisits every 6 days, sometimes missing major flood events (e.g., Hurricane Ida).
- Possible solution: Combine with more frequent optical sensor data.

Similar Studies Using Sentinel-1 and SNAP

- Sentinel-1 and SNAP successfully used in Morocco (Inaouene Watershed) and Bangladesh.
- Produced flood maps aiding emergency response and disaster management.

Conclusion and Future Recommendations:

Flood Susceptibility Maps (FSMs) are one of the most effective strategies for flood prevention and mitigation. Sentinel-1 has immense potential to provide high-quality data for flood mapping in New York. Future work involves potentially combining the data from Sentinel-1 with contemporary methods in flood mapping such as statistics and machine learning to prevent and minimize the damage of floods. Overall, Sentinel-1 serves as a good foundation for how further satellites can be used to create FSMs.

References:

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