Efficient Computations of Flooding Scenarios for the Coast of Maine

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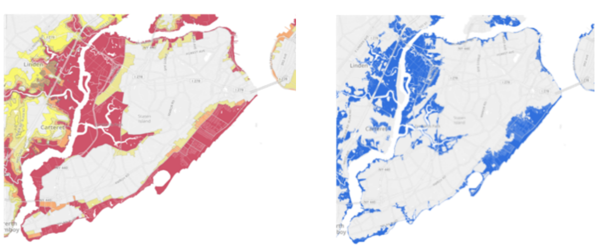
1. INTRODUCTION

In 2012, Hurricane Sandy wrought loss of life and damage in the billions of dollars to the eastern seaboard despite flood mitigation actions. Coastline management relies upon flood zone grids (FZG) in flood hazard maps to direct flood mitigation policy. The FZG derive from flooding models based upon historical data, but historical data does not account for today's rising sea levels produced by climate change and global warming. Communities were left unprepared for Hurricane Sandy, as deprecated flood hazard maps did not accurately predict Sandy's storm surge. Since then, the NOAA protocol utilizes geospatial LiDAR data to produce digital elevation models (DEM) that are incorporated with historical data to model terrain flooding and storm surges with a given sea level rise. Coastal flooding modelers now enter these very large data sets of DEM and FZG into ArcGIS and then manually bring the data sets through the newly prescribed NOAA protocol in a slow, laborious sequence.



Actual Impact **Predicted Impact**

Figure 1. Impact of Hurricane Sandy[1]

2. PROBLEM AND MOTIVATION

Through algorithm development, this research aimed to automate the NOAA protocol sequence to provide an efficient model of flooding scenarios in order to aid coastline management flooding mitigation policy decisions. This required developing an efficient algorithm that incorporates base flood elevations in the NOAA protocol calculations to model sea level rise. We sought to provide an efficient, unified framework for computing flooding utilizing large data sets of flood zone grids (FZG) and DEM LiDAR geospatial data.

3. BACKGROUND AND RELATED WORK

Since the devastation of Hurricane Sandy, NOAA has developed a protocol that allows flood scenario models to account for rising sea levels. This protocol has the following limitations:

- ArcGIS does not have a designated flood function, so the protocol is implemented via a long, tedious sequence of steps directed manually through the ArcGIS platform.
- Identification of connected components is performed by the operator of ArcGIS, which introduces possibility of human error into computations.
- The process is very slow on large data, taking many hours to complete.

4. APPROACH

This research aimed to develop algorithms that provide more efficient modeling of flooding scenarios utilizing FZG and DEM LiDAR geospatial data to automate the NOAA protocol sequence computations. DEM LiDAR data was analyzed to identify flooding in grid elevations and then interpolation methods identified storm surge points for the flood zone grids.

4.1 FLOODING

Digital elevation model (DEM) LiDAR geospatial data provides the elevation with respect to vertical datum and flooding is identified when a point in the grid's elevation is below the elevation of the ocean. Algorithm development utilizes graph traversal breath-first search to find the coast and places the points in a queue. Then while the queue is not empty, a point is removed from the queue and its neighbors are evaluated to determine if they are flooded. If they are flooded, then they are added to the queue and marked as flooded. In addition, flooding is identified when a point in the grid's elevation is reachable by the ocean. This requires determination of the height of storm waves at grid elevation data points reachable by flooding.

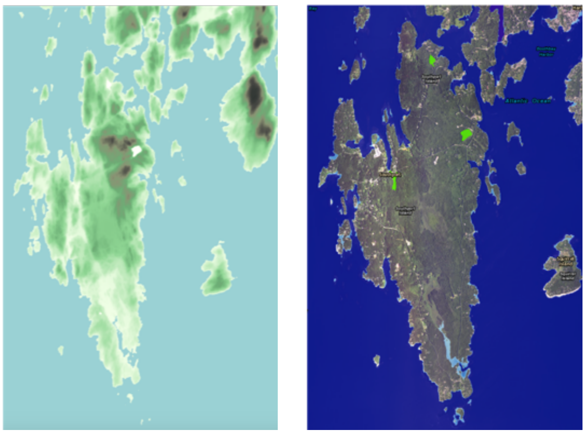


Figure 2. A juxtaposition of this research(left) and NOAA (right) at 6ft. sea-level rise for Southport, Maine

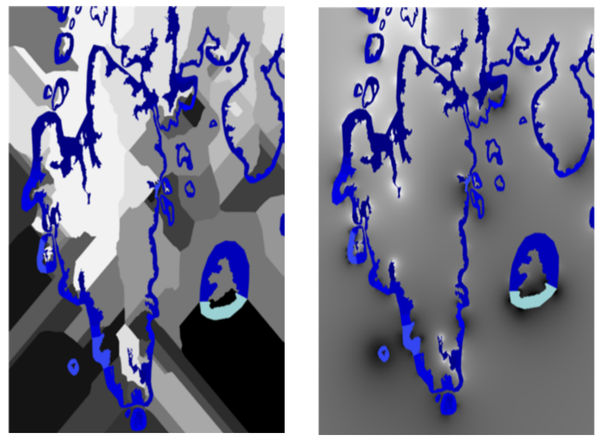
4.2 INTERPOLATION

In order to determine the extent of flooding attributable to storm surges, the flooding algorithm requires determination of the flood zone levels of the newly flooded areas. This was done though interpolation of the current flood zone map.

Various interpolation methods were explored to develop an algorithm to identify storm surge points for the flood zone grids and two were implemented. The interpolation methods employed for the flood zones grid are inverse distance weighted (IDW) and nearest neighbor (NN). These methods assign each point in the grid a particular flood zone value based on their distance to the original flood zone. Using the interpolated flood zones, the algorithm is then able to model flooding with storm waves and provides ability to input variables unlike ArcGIS. This research developed algorithms to produce flood grids that allow manipulation by a selected sea level. The algorithms also predict storm wave height and produce flood grids that simulate inundation moving from the coastline to areas inland.

5. RESULTS AND CONTRIBUTIONS

Lincoln County, Maine has recently completed coastal hazard research to study rising sea levels to predict flooding scenarios. This research examined grid coastline terrain datasets for Lincoln County that ranged from 1 million to 1,500 million points and results were compared to those achieved through the NOAA protocol.



NN (grayscale) **IDW (grayscale)**

Figure 3. The interpolated flood zone grids using nearest neighbor interpolation(NN) and inverse distance weighted(IDW) with the original flood zone grid (blue)for Southport, ME

5.1 RESULTS

Visual inspection of outputs from the newly developed algorithms compared to results produced through ArcGIS showed comparative relative consistency in the produced flood grids. Running with 2-meter LiDAR data, results mimicked ArcGIS (Figure 2). Results were produced within seconds rather than the hours and days required by utilizing ArcGIS. The program produced flooded grids and storm wave heights for Southport (15 million points) in 0.7 seconds, Bremen (13 million points) in 0.2 seconds, and Lincoln County (1 billion points in 6.5GB) in 80 seconds. The new algorithm demonstrated comparable flood grids with drastic time reduction for output over the days needed to utilize ArcGIS.

Showing 1ft, 3ft and 6ft of sea-level rise on top of the BFE map. Comparing with the results obtained with ArcGIS shows overall similarity, with some differences which we attribute to the interpolation used by ArcGIS.

5.2 CONTRIBUTIONS

Computing flooding scenarios through the newly developed algorithms presents a method that has the following attributes:

- Simple: Two-step process (interpolate, flood) is much simpler to use than ArcGIS.
- Free and open source
- Efficient: e.g. can flood Lincoln county, 2m DEM from LiDAR data, 900 million points in under 3 minutes compared to days in ArcGIS.
- Versatile: can model arbitrary sea-level rise and can combine sea-level rise with BFE and tidal surfaces.
- Currently assumes BFE and elevation grid are given in NAVD88 datum. Can be extended to incorporate any tidal surface (e.g. can compute flooding due to mean higher high water (MHHW) and sea-level rise).

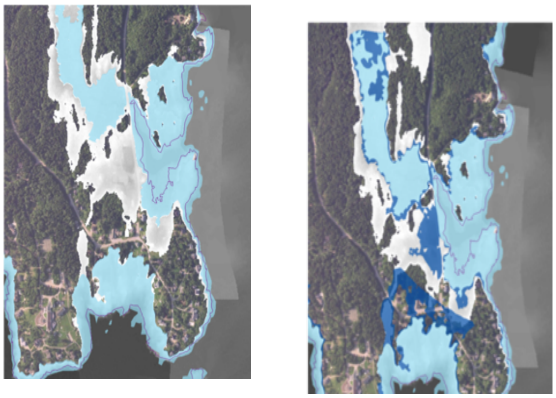


Figure 4. Flooding with 1ft. sea-level rise on top of the BFE map. BFE map in light blue, results with ArcGIS in dark blue, our results in white.

6. REFERENCES

[1] Keefe, John, Steven Melendez, and Louise Ma. "Flooding and Flood Zones | WNYC." Project.wnyc.org. November 10, 2012. https://project.wnyc.org/flooding-sandy-new/#12.00/40.7378/-74.0702.

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