Efficient Computation of Flooding Scenarios for the Coast of Maine

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  The Earth's temperature has been steadily increasing over the past century due to climate change and global warming. This increase has melted ice caps and forced thermal expansion, causing the amount of water in the sea to rise. Experts predict that the global sea level is expected to rise another 11 to 30 inches by the end of the century, flooding many cities[[1]](#endnote-1). Higher sea levels cause precipitation and deadly storm surges to travel farther inland than ever before, leads to the destruction of coastal communities. In particular, Maine has already been and will be drastically affected by the increase in storm events making its coastal communities more vulnerable. The Natural Resources Council of Maine predicts that not only will Maine lose millions of dollars in the destruction of infrastructure and real estate, but also will lose the breeding grounds of hundreds of animals including Maine’s most endangered birds, the Piping Plover, Saltmarsh Sparrow, and Roseate Tern[[2]](#endnote-2).

Environmentalists and urban planners want to be able to model and predict the areas susceptible to flooding, in order to flood proof structures, set insurance rates, and plan evacuation zones. The impacts that past storms have had on coastlines based on historical records is given in Base Flood Elevation (BFE) maps[[3]](#endnote-3). BFE maps designate which coastal areas have been flooded by historical one-in-one-hundred years storms. BFE maps are important tools for flood prediction; therefore it is important to have accurate and up-to-date BFE maps. For example the area flooded by Hurricane Sandy in 2012 greatly exceeded the boundaries of the BFE maps at the time, which had not been updated since the 1980’s.

As researchers contemplate sea level rise of 2ft or more, it is clear that future flooding models need to incorporate two types of flooding: flooding due to storm waves, as well as flooding due to sea level rise. Flooding due to storm waves, captured by the current BFE maps, is given by historical data (which regions were flooded by the past storms) and is relative to the current coastline, which has stayed unchanged for the past hundreds of years. With the sea levels rising, this will change the coastline, which will change the areas affected by storms. New flood models need to predict the future BFEs in the presence of sea level rise.

Existing work on modeling flooding uses a software system called ArcGIS. ArcGIS does not have a dedicated tool for modeling flooding, and furthermore it is very slow on big data. NOAA Office of Costal Management describes an approach to model SLR and BFE flooding in ArcGIS via a couple of functions that ArcGIS provides, such as intersecting a terrain with a horizontal plane and computing connected components[[4]](#endnote-4). This approach was implemented by previous Bowdoin student and Environmental Studies major Lizzie Kenny ’16. In her independent study project Lizzie described the process and the resulting flood maps. One of the findings of her work was that the process is computationally intensive, requiring many hours of server-time on top of manual input.

The goal of my project this summer is to develop an algorithm to model flooding due to the combined effects of sea level rise and increased flood events, and implement this algorithm in a tool that can be used to create flood maps for the coast of Maine. Put simply, my algorithm would take as input a digital elevation model of a terrain, an amount of sea level rise (for e.g. 2ft) and a current BFE map of the same terrain, and compute a new, overall flood map for a combined scenario of 2ft SLR + storm waves. From an algorithmic perspective, simulating flooding, i.e. water gradually coming inland, can be done with a breath-first search or a priority-based approach: first determine which points are ‘the sea’ (i.e. water that is connected to the periphery) and include them in a queue; then repeatedly remove a point from the queue and look at its neighbors; if a neighbor is not flooded yet and if it is also water or if it is land below the sea level rise, then it is added to the queue. The process ends when the queue becomes empty. This process needs to be extended to extrapolate the current BFE to the new, flooded coast. Ideally, this would be done simultaneously with the SLR flooding. Another idea is to interpolate the BFE inland before the SLR calculations. I will explore using nearest neighbor, first-accessed, and an average approach to determine the most realistic and accurate model.

From a computer science perspective, the challenge is to develop an algorithm that produces accurate results comparable to those obtained in ArcGIS, and runs efficiently on very large data. Professor Eileen Johnson has high resolution LIDAR data for the coast of Maine totaling many terabytes. Since ArcGIS is unable to handle big data, so far research has focused on processing a few tiles at a time. A few tiles can only hold enough data to model a county. With my tool I am hoping to be able to model flooding on larger areas, possibly more than one county at a time, and ideally the whole coast. From a practical perspective, this tool would be open source and easy to use, and would allow researchers and planners to easily compute various flooding scenarios in one shot on their laptops, without using ArcGIS.

I would like to work on this project to not only contribute to coastal Maine communities and wildlife, but to further my learning in ways not available in classrooms. I have been awarded the Maine Space Grant for the past two years at Bowdoin and have found them very fulfilling experiences. The research experience has provided me with the incredible opportunity for growth and has allowed me to explore my field outside of the classroom. I have already worked with terrains, DEMS, and LIDAR data while taking GIS Algorithms and Data Structures in the fall, giving me the necessary information to work with this large project. As a CS major headed into my senior year, I have taken the majority of CS classes offered by the department, providing me a solid foundation in this material. With this project, I will extend those experiences and apply them in a meaningful way.

1. "Sea Level Rise." National Geographic. January 14, 2017. Accessed February 26, 2017. http://www.nationalgeographic.com/environment/global-warming/sea-level-rise/. [↑](#endnote-ref-1)
2. "FAQs Regarding the Effect of Sea-level Rise in Maine." Natural Resources Council of Maine. February 21, 2017. Accessed February 26, 2017. http://www.nrcm.org/projects/climate/global-warming-air-pollution/effects-of-sea-level-rise-on-maine/faqs-regarding-the-effect-of-sea-level-rise-in-maine/. [↑](#endnote-ref-2)
3. "Definitions." Definitions | FEMA.gov. May 18, 2016. Accessed February 26, 2017. https://www.fema.gov/national-flood-insurance-program/definitions. [↑](#endnote-ref-3)
4. NOAA. Office for Coastal Management. *Detailed Method for Mapping Sea Level Rise Inundation*. January 2017. [↑](#endnote-ref-4)