A Toxic Relationship

Extreme Coastal Flooding and Superfund Sites

Appendix: Methodology

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Section 1
Methods for Determining Future Extent of the 100-Year-Flood Height/Zones with the Addition of Sea Level Rise

Definitions

100-year-flood height/zone. Term used to refer to either the height at which or the area where we would expect there to be a 1 percent annual chance of flooding.

Digital Elevation Model (DEM). A gridded spatial dataset in which each cell (similar to a pixel) represents the ground elevation at that point. In this way, a DEM allows us to represent a terrain's surface and its height relative to other values such as sea level height.

Tidal gauges. Measurement stations located along the coasts which continually sense and record the height of the surrounding water.

Interpolation. A means of estimating values of a continuous data layer when only select data points are available. For example, one might interpolate the temperature in a certain town if one has only temperature readings from weather stations in all the surrounding towns. The opposite of extrapolation.

Objective

Model the extent to which extreme flooding will change as sea levels rise across the East and Gulf Coasts.

Methodology

To determine the geographic extent of extreme flooding with sea level rise, we used what is known as the "bathtub model." This model, while relatively simple, allows scientists to estimate both the permanent and temporary flooding of the coasts that we are likely to experience as sea levels rise.

DATA ACQUISITION AND FORMATTING

In order to perform an analysis using this model, we utilized three datasets: (1) a DEM representing the current elevation of land along the coast (USGS n.d.); (2) location of tidal gauges with current flood height elevation (Buchanan et al. 2016; Tebaldi, Strauss, and Zervas 2012); and (3) sea level rise projections for the East and West Coasts (NOAA 2017). To prepare these datasets for use in the model, the following steps were carried out to convert all datasets to the same format, a gridded raster dataset that would create a continuous surface of data along the entire East and Gulf Coasts of the United States.

1. We downloaded all DEMs for states along the East and Gulf Coasts. These were then resampled to a coarser resolution (0.001 meter) and we mosaiced the tiles together for each state to improve processing times.
2. We downloaded both the tidal gauge location data (shapefile) and current flood height values. The flood height spreadsheet was reformatted and joined to the tidal gauge shapefile in R. Using a Python script, lines were drawn perpendicular to the coast that crossed through each tidal gauge to extend the flood height values over the coast. Points were generated along the lines 10,000 meters apart to allow for interpolation later. Using a Python script, the Natural Neighbor Interpolation method was used to create a raster dataset with the same resolution and extent of the state's DEM.
3. Sea level rise projections from the National Oceanic and Atmospheric Administration (NOAA) were downloaded and imported into ArcGIS Pro as a CSV and converted to shapefile point formats. The Natural Neighbor interpolation method was used to create gridded raster layers from sea level rise point data with the same resolution and extent as the DEM.

THE BATHTUB MODEL

These files were then input into a Python script that performed the bathtub model calculations. The script allowed us to perform the following tasks for each state, year, and scenario of interest:

1. The sea level rise layer was added to the 100-year-flood height and mean higher high water layers in order to create a raster dataset representative of the total water level (TWL) for each year and scenario of interest. TWL is representative of the height we would expect the new 100-year-flood height to be at when taking sea level rise into account.
2. We then subtracted the DEM layer from the TWL layer which resulted in a new raster layer that represents the areas we would expect to be flooded. All cells within this new dataset with a value greater than 0 would be expected to be flooded.
3. With this raster, we then created an additional raster that assigns all cells with a value greater than 0 with a value of 1.
4. We then used the region group tool to determine which cells would be hydrologically connected or disconnected and then converted the data to a polygon shapefile. This new shapefile shows the extent of the new 100-year-flood height drawn out along the entirety of the East and Gulf Coasts.

Once these steps were carried out for each state, year, and climate scenario of interest, the flooding extents were merged and dissolved into one continuous flooding layer along the East and Gulf Coasts for each year and climate scenario.

Section 2
Methods for Proximity Analysis of Environmental Justice Communities near Superfund Sites at Risk of Flooding

Definitions

Environmental justice. The term environmental justice refers to the condition in which low-income Indigenous, communities of color, and low-income communities are disproportionately overburdened with environmental contamination and hazards.

Environmental justice community. For the purposes of this study, we developed a systematic, quantitative categorization by classifying census tracts as environmental justice communities and non–environmental justice communities using race and poverty variables.

GIS (geographic information systems). Geographic analysis software and data management systems such as ArcGIS, ArcGIS Pro, or QGIS. GIS can also refer to geographic information science, the study of geographic information and the means through which it can be obtained, managed, analyzed, and presented to increase understanding of geographic phenomena.

Census block group. The smallest geographic unit at which the US Census Bureau provides data. A block group is made up of a collection of census blocks—defined by roads, streams, and other physical phenomena—from within a census tract whose identification numbers start with the same number. For example, a block group could be made up of all blocks within a census tract whose ID number starts with 300 (USCB 2017).

Buffer. Within the context of GIS, a zone around a geographic feature defined by an often-predefined distance. For example, a buffer around a point location such as a PFAS-contaminated facility would be shown as a circular region with a predefined radius (e.g., one, three, or five miles) whose center intersects with the facility location.

Objective

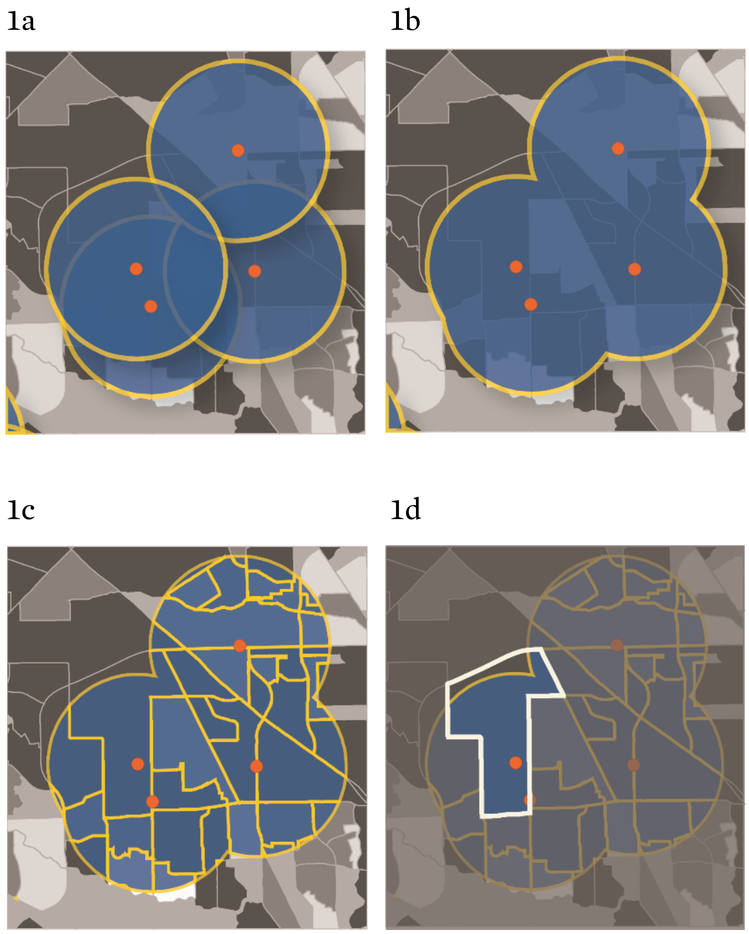
To determine whether people of color and low-income households are more often found living around Superfund sites at risk of flooding due to sea level rise than White and higher-income households.

Methodology

To estimate the number of people near coastal Superfund sites at risk of flooding, a buffer analysis was carried out using the geographic analysis software ArcGIS Pro and the Python coding language. Site locations were obtained from the Environmental Protection Agency's Facility Registry Service database, which included the location of 9,689 Superfund sites located throughout the United States. This list contains the location of sites that are being actively remediated as Superfund sites (i.e., they are listed on the national priority list) or are proposed to be listed. The SEMS also contains the location of sites that are in the screening and assessment phases for possible inclusion on the list. While we acknowledge that not all sites in the SEMS list will ultimately be designated as Superfund sites, it is important to note the potential long-term risks for these facilities, all of which contain harmful chemicals. From here on we refer to all these SEMS-listed sites as "Superfund sites." We took the following steps to carry out the analyses :

1. The first part of this analysis was to determine which Superfund sites will be considered at risk of future flooding given the high, intermediate-high, intermediate, and low climate scenarios from NOAA in the years 2040, 2060, 2080, and 2100. To do this, we superimposed the Superfund sites location data with the flooding extent for each year and scenario of interest. In addition to those located within the flooding extent, we also included sites within 200 meters of the flooding extent boundaries to account for the fact that we were using one-dimensional point data to represent a two-dimensional area where hazardous materials are found.
2. The second part of this analysis estimated how many people lived in three buffer zones, which, for the purposes of this analysis, we defined as the number of people living within a one-mile, three-mile, and five-mile radius near a Superfund site considered at risk of future flooding. To do this, we selected at-risk Superfund sites using the flooding extent layers (see Step 1) and drew circular buffer zones around each with a one-, three-, and five-mile radius using the buffer analysis tool in ArcGIS Pro. We then imported census block group data from the US Census Bureau. Many census block groups (which were polygons) fell partially outside the buffer zones; therefore, to estimate the number of individuals living within each buffer zone more accurately, we calculated the percentage of land area of each census block group located within each buffer zone, using the tabulate intersection tool. The determined percentage of land area for each census block group was then multiplied by the total number of individuals within that census block group. This provided the total number of individuals living within a specific census block group that fell within a buffer zone. The estimated number of individuals within all census block groups falling within a buffer zone, either fully or partially, was then summed to estimate the total number of individuals living within that buffer zone. This process was repeated for all buffer zones (one, three, and five miles) surrounding a point location (see Figure A-1). We assumed an even distribution of the population throughout the census block group.

Figure A-1. Calculating Superfund Site Impacts on Nearby Communities



This figure illustrates a hypothetical calculation of the population near a Superfund site. First, buffer zones are drawn around a Superfund site (1a), then the buffer zones are dissolved together (1b) in order to eliminate double counting of census block groups that fall within multiple buffer zones. Boundaries of all census block groups within the dissolved buffer zones are added (1c). For census block groups that fall partially outside of the buffer zone (highlighted example in 1d), the percentage of the region inside the buffer zone (shown in blue) is applied to the population of the whole census block. In this hypothetical example, the buffer zone covers 90 percent of the highlighted census block's geographical area. If 100 people live in this census block group, we would estimate that about 90 people from that block group live within the buffer zone.

3. We calculated the number of low-income households and people of color living within each buffer zone of an at-risk Superfund site. First, we determined the number of people of color within each block group. This number was calculated by taking the total population of each block group and subtracting the number of individuals who identified as “White alone” in the US Census American Community Survey (USCB 2017). The number of non-White individuals in each block group was then multiplied by the percentage of land area within the buffer region to calculate the number of non-White individuals living within the buffer region. To calculate the number of low-income households within each buffer zone, similar methods were used. Low-income households were defined by the number of households with income below the poverty line within the last 12 months (USCB 2017). The number of low-income households within each census block group was multiplied by the percentage of land within the buffer zone to calculate the number of low-income households within the buffer zone.
4. To determine whether certain groups are at a disproportionate risk from flooding of coastal Superfund sites, we compared the observed number of households and individuals from each demographic group living in each buffer zone to expected values. To calculate the expected number of individuals in each block group, the percentage of low-income households or people of color was calculated for coastal counties overall along the East and Gulf Coasts. This percentage was then multiplied by the total estimated number of individuals within a buffer zone for a point location, generating an expected number of people for each demographic group of interest. For example, 13.51 percent of households in coastal counties are recorded as being low-income; therefore, we expect 13.51 percent of households within the buffer zones to be low-income.

References

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