UrbanFootprint

TECHNICAL DOCUMENTATION

UrbanFootprint Coastal Flood Methodology

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Overview

Coastal flooding typically occurs during seasonal high tides and storms. As sea level rises, floods are expected to happen more frequently and during less extreme events. Low-lying coastal areas are most susceptible to these changes, and no datasets are publicly available that demonstrate comprehensive coastal flood risk with:

- Sufficient spatial resolution to effectively represent property scale risk and damage.
- Information about inundation depth and frequency of flooding.
- Future inundation projections from the combined effects of storm surge and sea level rise.

The UrbanFootprint Coastal Flood dataset comprehensively assesses coastal flood risk by integrating storm surge, hurricane-induced surge, and sea level rise. It offers depth annual probabilities at the parcel scale, accounting for present-day and future horizons and climate conditions.

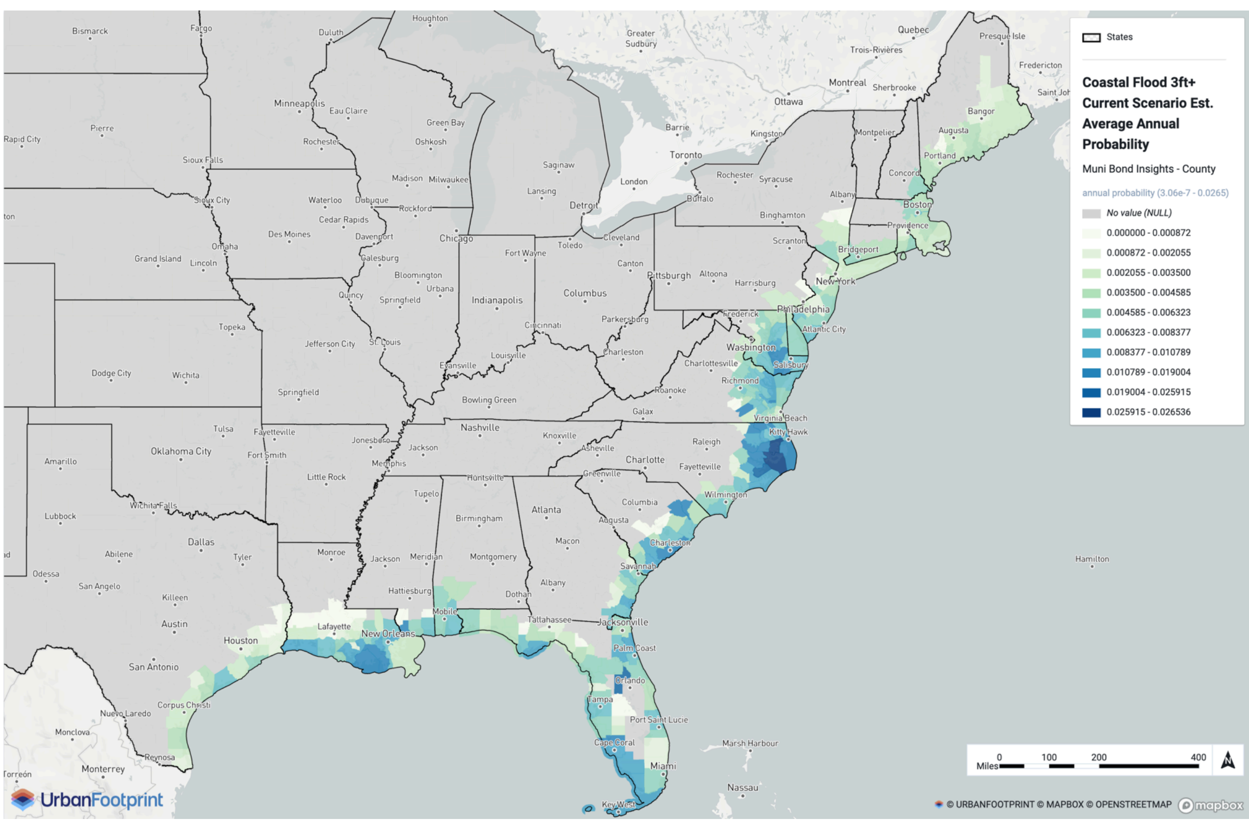

Figure 1: Annual Probability of Exceeding 3 Feet of Coastal Flood Depth.

The UrbanFootprint Coastal Flood dataset serves as a resource for various sectors such as policymakers, insurers, the energy sector, and many others, playing a vital role in enhancing resilience amidst the challenges posed by our dynamic climate.

Data Sources

NOAA Storm Surge Risk

The National Oceanic and Atmospheric Administration (NOAA) provides storm surge risk from tropical cyclones using the hydrodynamic Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model.

- **Source:** National Oceanic and Atmospheric Administration
- **Link:** Storm surge risk inundation depths

UrbanFootprint Hurricane Winds

UrbanFootprint Hurricane Winds is built using 10,000 years of synthetic present and future tropical cyclone tracks derived from the International Best Track Archive for Climate Stewardship (IBTrACS).

- **Source:** UrbanFootprint
- **Link:** UrbanFootprint Hurricane Winds

NOAA Sea Level Rise Projection

The mean sea level rise information along the coast comes from the Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force 2022 technical report titled "Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines". The Interagency Task Force offers downscaled sea level projections created from AR6 in global and regional sea level rise scenarios for the United States where the scenarios are based on targeted amounts of sea level rise.

- **Source:** National Institute of Standards and Technology
- **Link:** Sea Level Rise projections

UrbanFootprint Parcel Base Canvas

The UrbanFootprint Base Canvas is a geospatial dataset that reflects existing land use and demographics at the parcel or census block resolution. The UrbanFootprint Base Canvas creation process incorporates a number of data sources to populate the attribute columns, including population and housing data from the decennial census and American Community Survey; employment data from the Longitudinal Employer-Household Dynamics (LEHD) program; point of interest data from various sources; and parcel data for over 160 million US parcels.

- ➔ **Source:** UrbanFootprint
- ➔ **Link:** Base Parcel Canvas Creation Methodology

Specification

Spatial Resolution

Coastal Flood risk results are presented at the parcel level, aligned with the UrbanFootprint Base Canvas. We use the fine resolution 10×10 m grid storm surge inundation depths and annualized probabilities of wind speed exceedance at 0.1×0.1 degree based on the Saffir-Simpson Hurricane Wind Scale to calculate the hurricane-induced storm surge at the UrbanFootprint Parcel Base Canvas scale.

Spatial Extent

UrbanFootprint Parcel Base Canvas level data is available for most parts of the United States; however, storm surge data is limited to the coastline from Texas to Maine. Consequently, coastal flood risk assessments are also confined to these regions.

Inundation Depths

The depths are derived from the Maximum Envelope of Water (MEOW), in line with NOAA Storm Surge data. MEOW represents the extreme surge values generated from multiple simulations of storms with varying intensities, speeds, and directions. The specific storm track that generates the MEOW for a particular location is unknown, meaning that the MEOW values for adjacent cells might come from entirely different simulation runs. NOAA uses MEOWs to account for uncertainties and ensure that no critical storm track with extreme values is overlooked.

Time Horizons

We model three time horizons, consistent with the UrbanFootprint Hurricane Winds model. The first is a “present-day conditions” time horizon, representing the risk under current climate conditions. These conditions and their effect on coastal flood inundation formation is derived from the storm surge data and historical record of hurricane tracks (called the IBTrACs dataset) from 1980 to 2017.

For “future” time horizons, representing the risk under future climate conditions, we align with the UrbanFootprint Hurricane Winds model. This includes the “average climate conditions from 2015-2050” under an SSP5-8.5 GHG emission pathway, which we assume corresponds to the conditions of 2030. We also provide SSP2-4.5 for 2030 and both SSP2-4.5 and SSP5-8.5 for 2050.

Methodology

Assumptions

- NOAA reported Storm Surge Maximum Envelopes of Water (MEOW) depths for any given location correspond to the UrbanFootprint Hurricane Winds probability of exceeding a windspeed threshold at the same location, accounting for the differences in topography and bathymetry and the differences between the respective local hurricane wind climates.
- Any location on the coast experiences a uniform distribution of wind speeds despite the potential change in elevation.

Hurricane Annual Probabilities of Exceedance Estimation

The annual probabilities of exceeding a specific wind speed are derived using UrbanFootprint Hurricane Winds. The Hurricane Winds model is built using the derived 10,000-year synthetic tropical storm dataset for current and future conditions. It identifies maximum wind speeds using wind field estimation and fits Generalized Pareto Distribution (GPD) probability distributions for the maximum wind speed distribution at a given location. The detailed methodology can be found in the UrbanFootprint Hurricane Winds Methodology.

Combining the Datasets

We combine storm surge inundation depth data and hurricane probabilities of exceedance to assess the hurricane-induced impact on surge depths and calculate the annual exceedance probability for any flood depth. We assume the surge depth for a given Saffir-Simpson Hurricane Wind Scale category (categorized on a scale of 1 to 5 based solely on a hurricane's maximum sustained wind speed) is a result of the induced surge from the corresponding tropical cyclone category. With both assumptions, we can establish that for any grid cell, the surge value from NOAA has exceedance probabilities equal to the Hurricane Wind Model probabilities. This accounts for the spatio-temporal occurrence of the hurricane and surge. For example, if a grid experiences 5 feet of storm surge inundation for category 1 and has a 0.001% annual probability of exceeding wind speeds equal to or greater than category 1, then the annual probability of flood exceeding 5 feet of depth is 0.001% for that grid cell.

We overlay both NOAA storm surge and UF Hurricane Wind Model data with the UrbanFootprint Parcel Base Canvas, and for every parcel we fit a logistic function over five pairs of storm surge inundation and hurricane wind probabilities $[D_c P_c]$, where c corresponds to hurricane category.

$$f(P) = \frac{1}{1+e^{a+kD}}$$

where

- D = Initial storm surge depth
- a = constant parameter, ensuring that the function is finite and limiting zero
- k = coefficient that scales the impact of storm surge depth DDD.
- P = Probability of exceedance

The parameters a and k are determined through calibration, allowing the function to accurately reflect the relationship between wind speeds, storm surges, and flood probabilities.

After the function is fit, we calculate the annual probability of exceeding flood depths within the range of 0 feet to 24 feet for every parcel. For future time horizons, to accurately account for climate change-driven compounding effects, we adjust the storm surge depths with sea level rise inundation before fitting the logistic function.

Local Sea level rise was added by climate scenario to storm surge data using the Inverse Distance Weight (IDW) method. With limited NOAA stations covering the USA coastline, we filtered parcels within 20 kilometers of the station to establish a coastal boundary. We apply inverse distance weighting to spatially interpolate the mean sea level rise from the NOAA station data and add this estimated sea level rise to all parcels within the 20-kilometer buffer coastal boundary

$$Z_p = \frac{\sum_{i=1}^{n} \frac{Z_i}{d_i}}{\sum_{i=1}^{n} \frac{1}{d_i}}$$

where,

- Z_p = estimated mean sea level rise at parcel centroid
- d_i = distance between the i^{th} station and the parcel centroid
- Z_i = mean sea level rise at i^{th} station

Factoring in these components uniquely allows the UrbanFootprint Coastal Flood dataset to be both forward-looking and climate-adjusted to account for the combined effects of storm surge, hurricane, and sea level rise on coastal regions.