Assessment of Compound Coastal-Riverine Flooding Risks Under Climate Change along the U.S. Coasts

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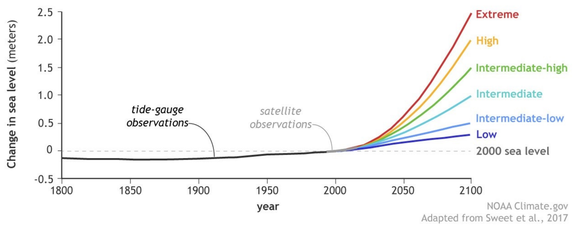
Introduction

Coastal cities are exposed to multiple flood drivers such as extreme coastal **high tide**, **storm surge**, and **extreme river discharge**. The interaction among these flood drivers may cause a compound flood event that could exacerbate flood impacts and cause huge social and economic losses.

Despite several recent studies on interaction between extreme sea levels and river discharges, a comprehensive assessment of impact of climate change on compound coastal-riverine flooding has not been explored along the coastal U.S. This research gap is important due to several reasons.

First, climate change is expected to increase the level of compound coastal-riverine flood hazard through higher extreme sea levels and river flows

Past And Projected Changes In Global Mean Sea Level



Second, a comprehensive bivariate flood hazard assessment based on impact flood thresholds is lacking.

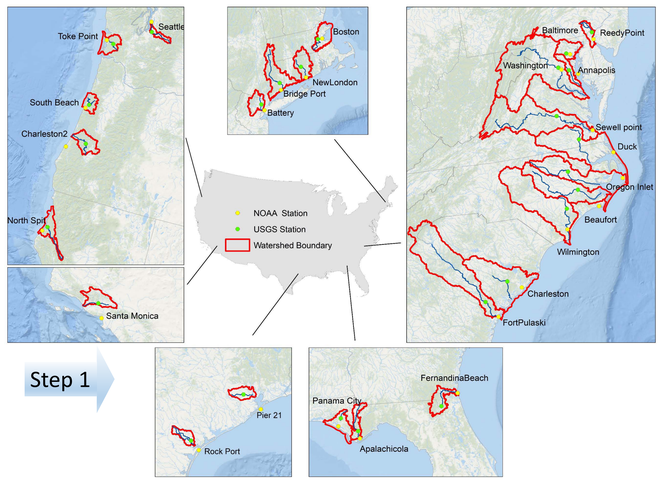
Coastal and Riverine Flood Classification

Minor: Minimal or no property damage.

Moderate: Some inundation of structures and roads and has relatively considerable damages to private and commercial property.

Major: Inundated area and infrastructure impact escalate significantly.

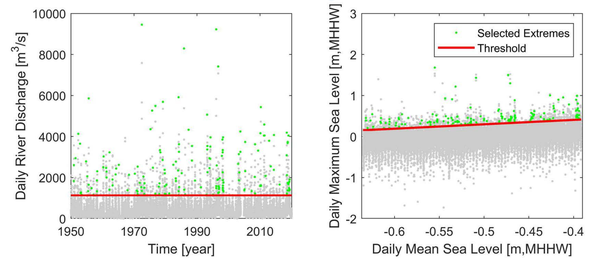
Materials and Methodology



Step 1

1. Selecting datasets of sea levels and river discharges along the coastal CONUS
2. Selecting pairs of extreme values for compound coastal-riverine analysis using the threshold-excess method
3. Quantifying Joint Return Period (JRP) of extreme sea levels and river discharges using the selected pairs
4. Assessing JRP of floods exceeding both major coastal and riverine thresholds under current and future conditions
5. Assessing changes in risk of failure (RF) over design lifetime

Step 2



Step 3

$$F_{XY}(x,y) = C(F_X(x|\theta_x), F_Y(y|\theta_y)|\theta_c)$$

$$P_{AND} = 1 - F_X(x^*|\theta_x) - F_Y(y^*|\theta_y) + C(F_X(x^*|\theta_x), F_Y(y^*|\theta_y)|\theta_c)$$

$$JRP = \frac{\lambda}{P_{AND}}$$

Step 4

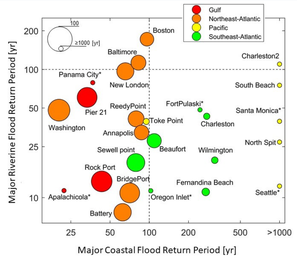
Future sea level rise and river discharge scenarios :

- Intermediate-Low and Intermediate sea level rise scenarios from Sweet et al.(2017)
- Ten-member ensemble streamflow projection derived from runoff simulated by Naz et al. (2016). The projected total daily runoff is simulated by the Variable Infiltration Capacity (VIC) hydrologic model forced with ten dynamically downscaled Global Climate Models (GCMs) from the Coupled Model Intercomparison Project phase 5 (CMIP5) archive under the RCP 8.5 emission scenario.

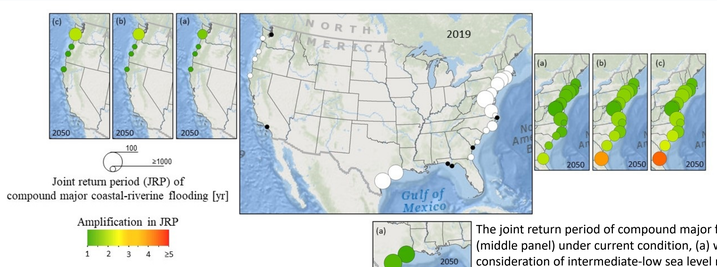
Step 5

$$RF = 1 - \prod_{t=1}^{n}\left(F_X(x^*|\theta_x^t) + F_Y(y^*|\theta_y^t) - C\left[F_X(x^*|\theta_x^t), F_Y(y^*|\theta_y^t)\right]|\theta_C^t\right)$$

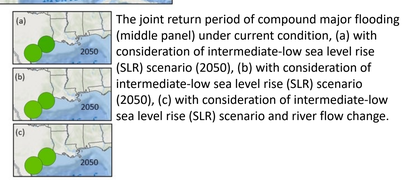
Results



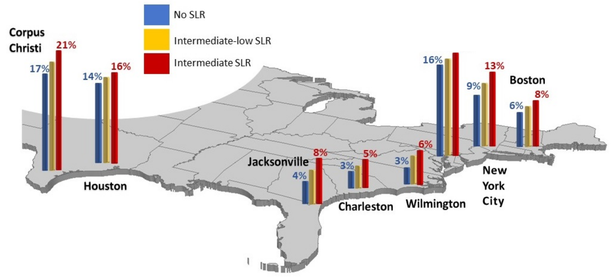
The relationship between the return period of major coastal and riverine flooding based on univariate analysis and the corresponding joint return period (JRP) based on bivariate analysis.



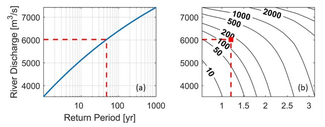
(a) Intermediate-low SLR
(b) Intermediate SLR
(c) Intermediate SLR + Changes in extreme river flows



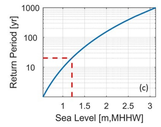
The joint return period of compound major flooding (middle panel) under current condition, (a) with consideration of intermediate-low sea level rise (SLR) scenario (2050), (b) with consideration of intermediate-low sea level rise (SLR) scenario (2050), (c) with consideration of intermediate-low sea level rise (SLR) scenario and river flow change.



Risk of failure due to a compound major flooding (RF_{Major}) after 30 years of design life (2020-2050)



Marginal distribution based on generalized Pareto Distribution for (a) extreme river discharges, (c) extreme sea levels; (b) joint return period of extreme paired data based on the selected copula.



Highlights

- The northeast Atlantic and western part of the Gulf coasts are experiencing the highest compound major flood probability under current conditions.
- However, future sea level rise scenarios show emerging high compound major flooding probability along the southeast Atlantic coast.
- The impact of changes in extreme river flows is found to be negligible in most of the locations except the southeast Atlantic coast. However, even in this region, its impact is considerably less than that of sea level rise.
- The coastal cities along the southeast Atlantic coast are expected to be exposed to double risk by midcentury under the intermediate sea level rise scenario. These findings highlight the potential for compound major flooding to produce destructive impacts more frequently if sea levels continue to rise, which illustrates the need for consideration of joint behavior of extreme sea levels and river discharges in local level planning and adaptation

References and Acknowledgment

Naz, B. S. et al. Regional hydrologic response to climate change in the conterminous United States using high-resolution hydroclimate simulations. Glob. Planet. Change 143, 100–117 (2016).
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