The role of locally generated rainfall and remotely driven storm surges in compound flooding

MACH Megalopolitan Coastal Transformation Hub

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Motivation and background

Studies of future compound flooding rely on flood driver information from general circulation models (GCMs). However, GCMs often lack the resolution to capture localized rainfall events that can create compound flooding when combined with moderate surges or high tides.

Studies using synthetic tropical cyclones (TCs) for compound flood assessments often rely on a set of selected events passing close to the study site. Cyclonic activity from distant systems also can generate storm surges that propagate into the study region, and when combined with high tides and rainfall can contribute to compound flooding.

In this study, we use a multivariate statistical method to assess the role of these "non-classified" storms (neither caused by TCs or extratropical cyclones (ETCs)) on compound flood potential.

Study sites

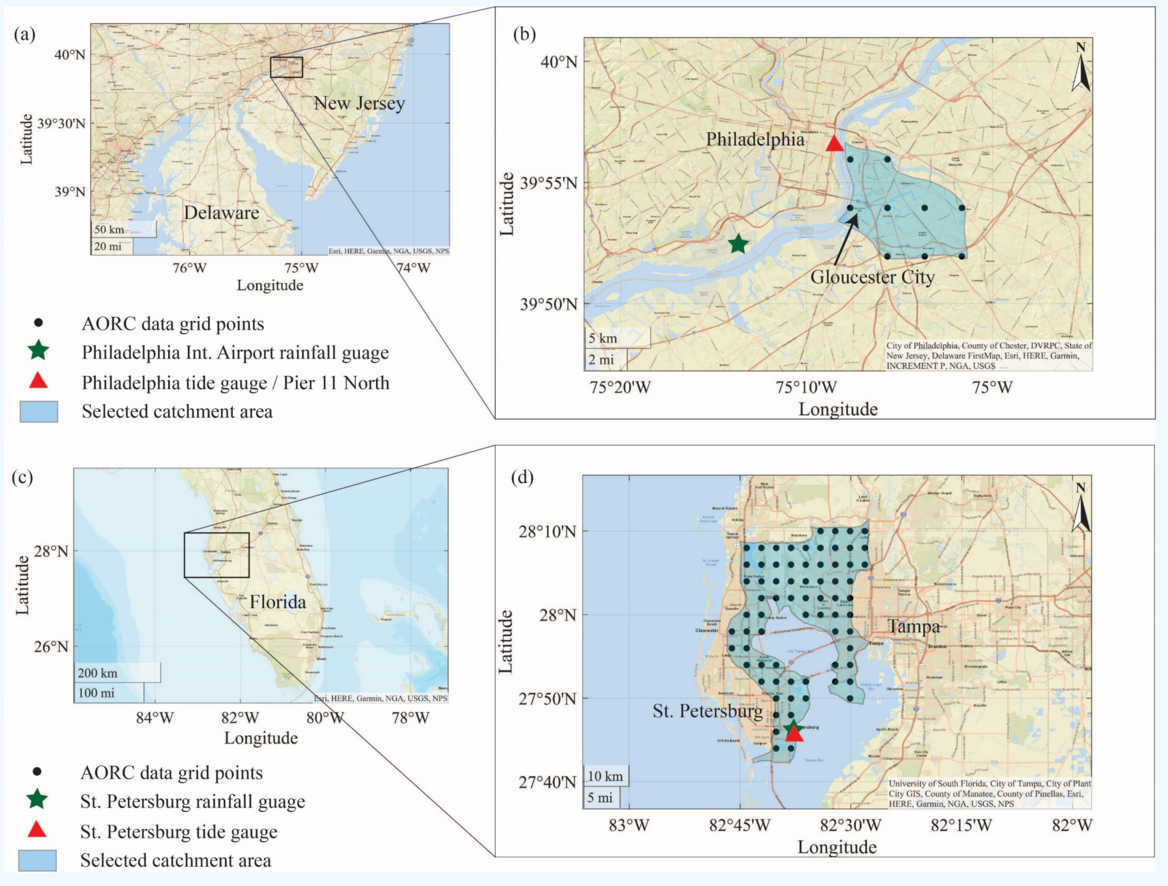

Fig. 1: Case study sites Gloucester City, NJ and St Petersburg, FL.

Data

Water Levels	Temp. coverage	Resolution
Philadelphia tide gauge	1901-2021	Hourly
St. Petersburg tide gauge	1950-2021	Hourly
Cyclone Track data		
HURDAT.2	1851 – 2021	6 hours
ET tracks using Lagrangian T.A.	1950 – 2021	6 hours
Rainfall data		
AORC	1979 – 2021	Hourly (4 km)
Gauge data at Philadelphia Int. Airport	1900 - 2021	Hourly
Gauge data at St. Petersburg	1950-2021	Hourly

Method

1 Bias correction of RF gauge data

$$RF_{Mod,x} = F_\gamma^{-1}\left(F_\gamma\left(RF_{MS,x} \mid \alpha_{MS}, \beta_{MS}\right), \mid \alpha_{AORC}, \beta_{AORC}\right)$$

$RF_{Mod,x}$: bias-corrected measured value,
$RF_{MS,x}$: original measured value,
F_γ : Gamma distribution with α and β as scale and shape parameters.

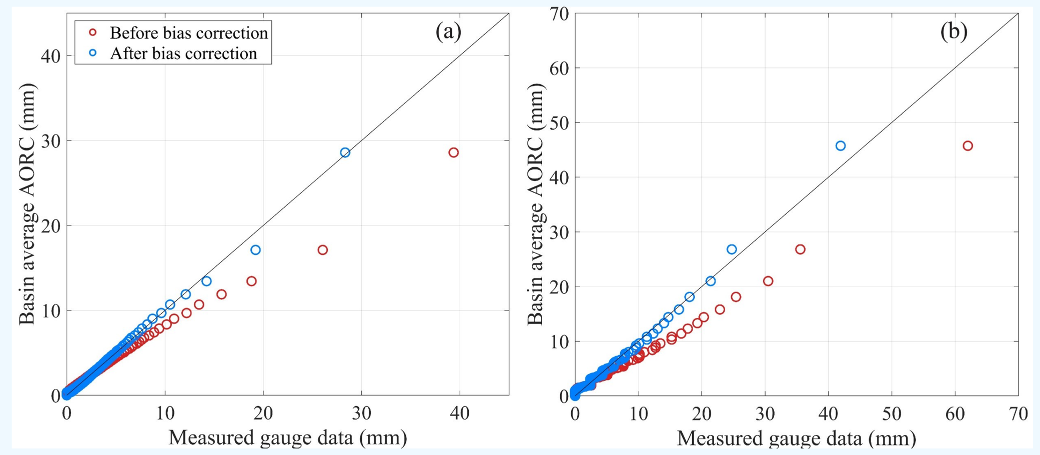

Fig. 2: Q-Q plot of gauge data vs AORC data

2 Define extreme events using peaks over threshold (POT) two-sided sampling approach

3 Stratify the extreme events under 4 scenarios:

Scenario	Conditioning NTR	Conditioning RF
1	TC and non-TC	TC and non-TC
2	TC and non-TC	TC and ETC
3	TC and ETC	TC and non-TC
4	TC and ETC	TC and ETC

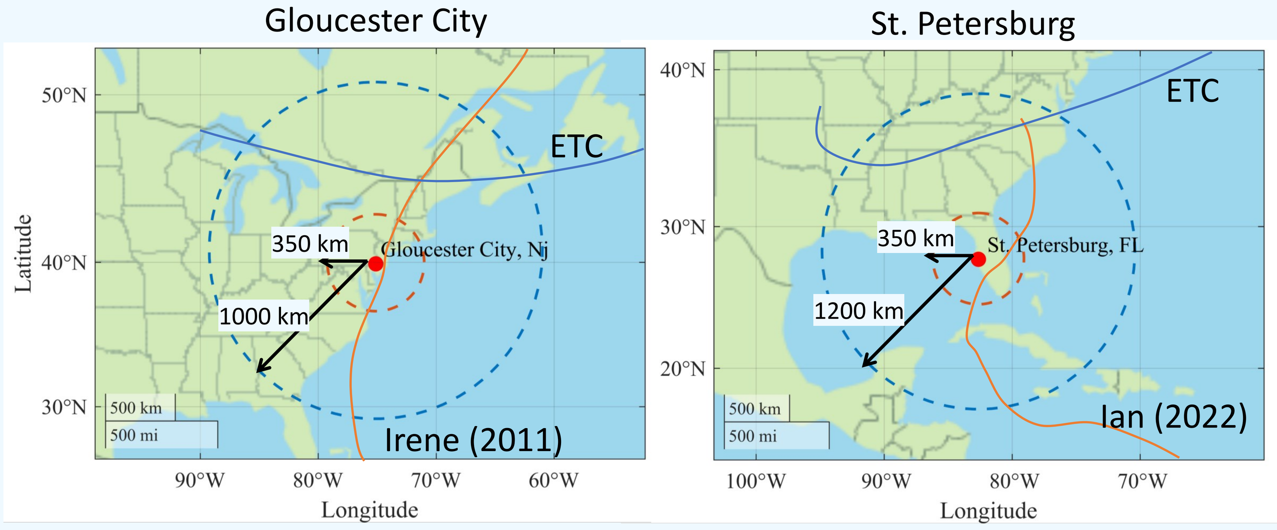

Fig. 3: Examples of TC and ETC tracks passing through the search radii

4 Select appropriate marginal distributions

5 Select appropriate copulas for each stratified pair of samples

6 Derive the joint probability distribution of each stratified sample

7 Derive the combined joint probability distribution for each scenario

8 Quantify the changes in the combined joint probability distribution in each scenario

Results

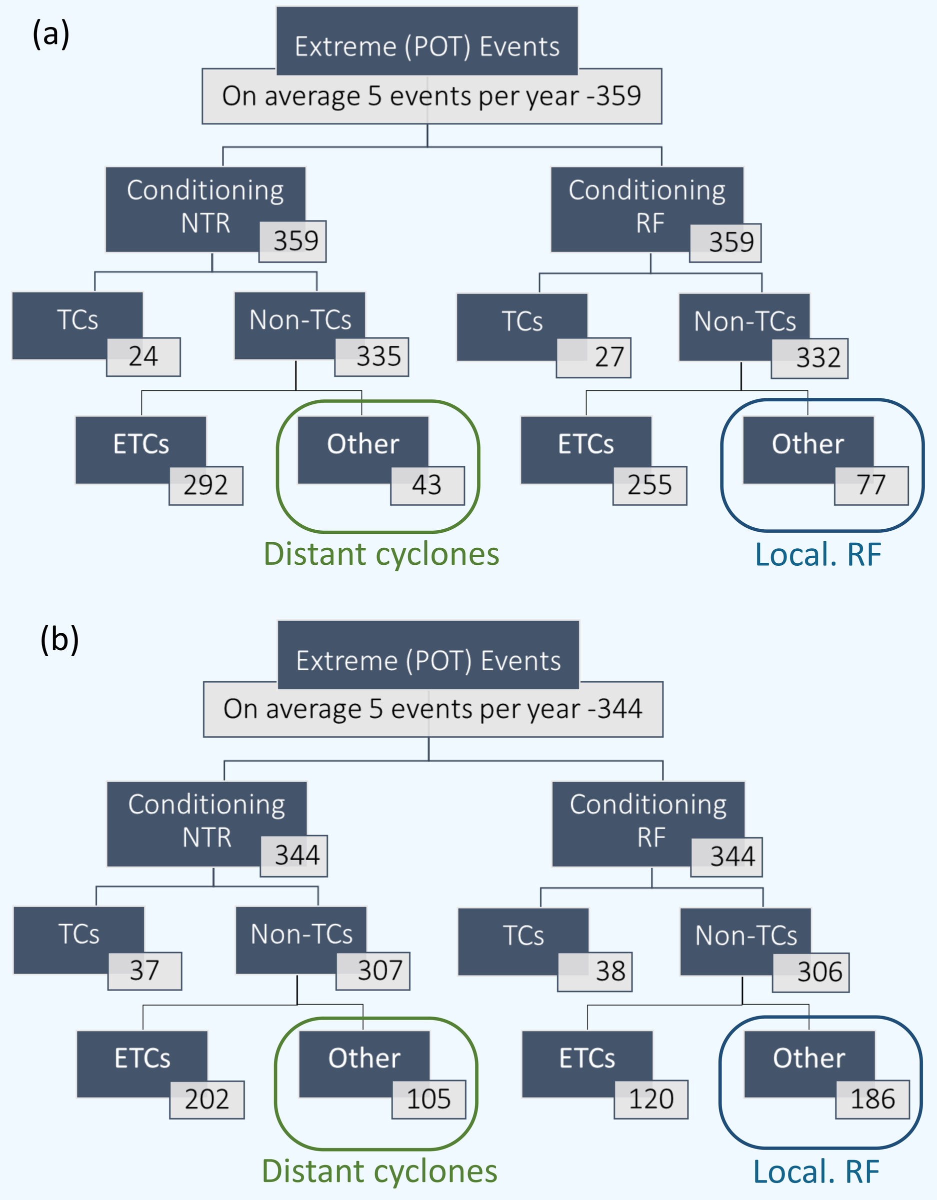

Fig. 4: Stratification process of (a) Gloucester City and (b) St. Petersburg

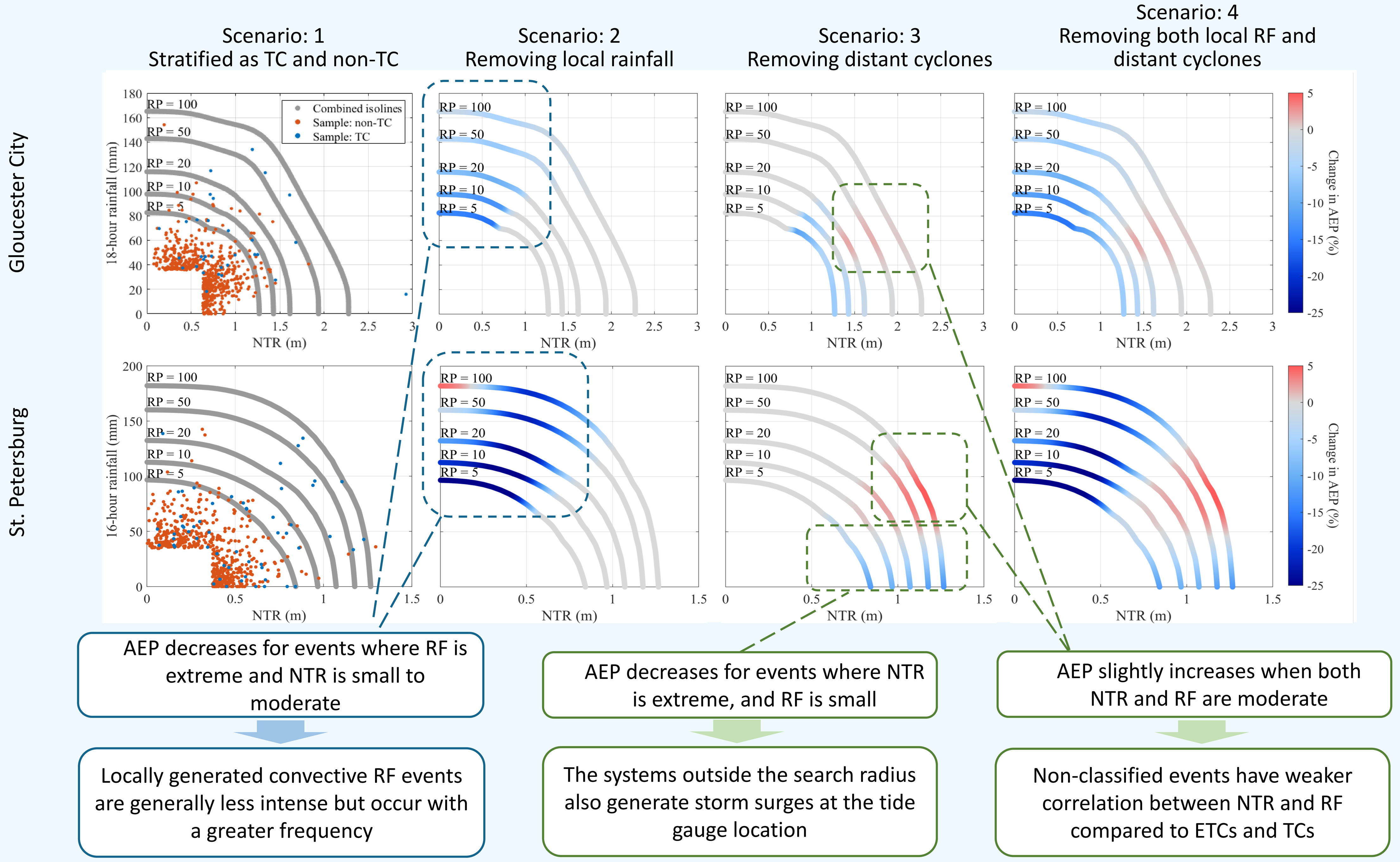

Fig. 5: Joint probability distributions

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References:

Maduwantha, P., Wahl, T., Santamaria-Aguilar, S., Jane, R., Booth, J. F., Kim, H., and Villarini, G.: A multivariate statistical framework for mixed storm types in compound flood analysis, Nat. Hazards Earth Syst. Sci., 24, 4091–4107, https://doi.org/10.5194/nhess-24-4091-2024, 2024.

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