Conference Title: 2016 CoRP Symposium
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Title: **Flood Risk Analysis in New York City Applying Nonparametric Simulation on Radar Rainfall Data**

Type of Presentation: Oral

Short Abstract:

Flood response in an urban area is the product of interactions of spatially and temporally varying rainfall and infrastructures. Scenarios that properly represent likely storm tracks through the city and the associated space-time patterns of rainfall can help improve the operation of urban hydrologic systems. The goal of this study is to apply simulation based approach to reproduce spatially dependent storm data and use it to quantify the risk of extremes in New York City (NYC) and to compare with the current design criteria. In this regard, radar data stage IV from 2002-2015 is employed to determine extreme rainfall events and examine the spatial consistency between them in NYC. A nonparametric copula-based simulation approach is applied to the spatial fields with arbitrary dependence structures and marginal densities. The nonparametric simulator uses log-spline density estimation in the univariate setting, together with a sampling strategy to reproduce dependence across variables through a nonparametric numerical approximation of the underlying copula function. Results indicate current design criteria of NYC underestimates the extreme rainfall in boroughs of Manhattan and Staten Island while overestimates the events over Brooklyn and Queens area. Therefore, instead of stationary design criteria, we propose a spatially dynamic design criteria for NYC to meet the extremes.

Risk Analysis of New York City Extreme Rainfalls Applying Nonparametric Simulation on Radar Rainfall Data

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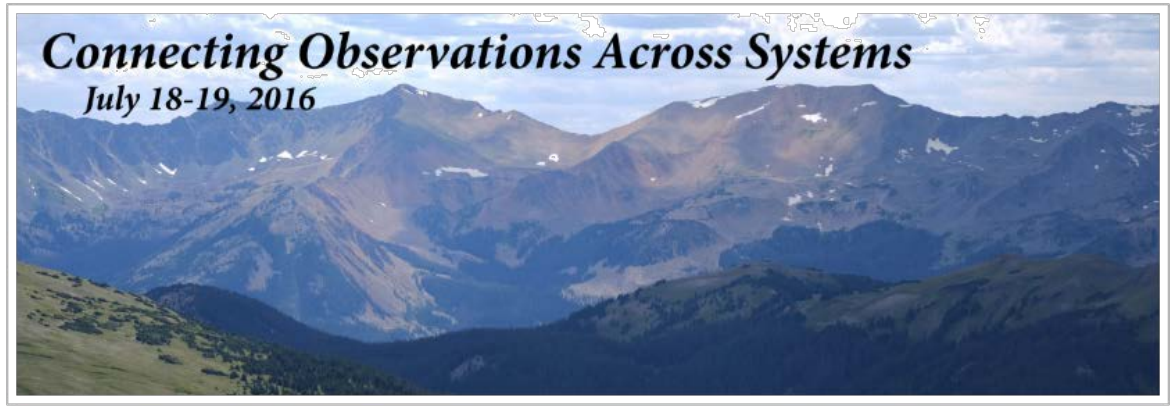
NOAA/NESDIS CoRP Symposium



NOAA CREST

CUNY The City University of New York

The City College of New York

Background and Goal:

Storm Design for City Scale

Rainfall data with High Spatial Resolution

Radar Rainfall Data Stage IV (1-hour, 4km.4km) from 2002

Limited Time History in Data Set

Unrealistic Risk Analysis

Regional Frequency Analysis

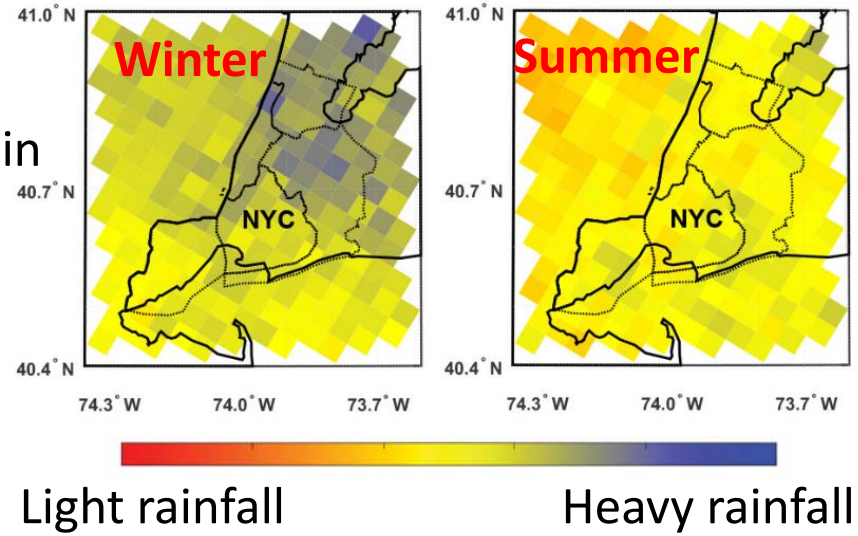
Simulation of the Storm Field

- Traditional approach of IDF curves
- Substitution of space for time

Simulation Goal:

Goals:

1. Reproduce extreme rainfall sequences.
2. Characterizing the original data ***features***.



- Temporal Trend
- Spatial Dependence
- Multivariate simulation using notion of Copula

3. Quantify the risk of extreme rainfall in NYC.

Simulation Concept:

Sklar's Theorem (1959):

Any multivariate joint distribution can be written in terms of univariate marginal distribution functions and a **copula**.

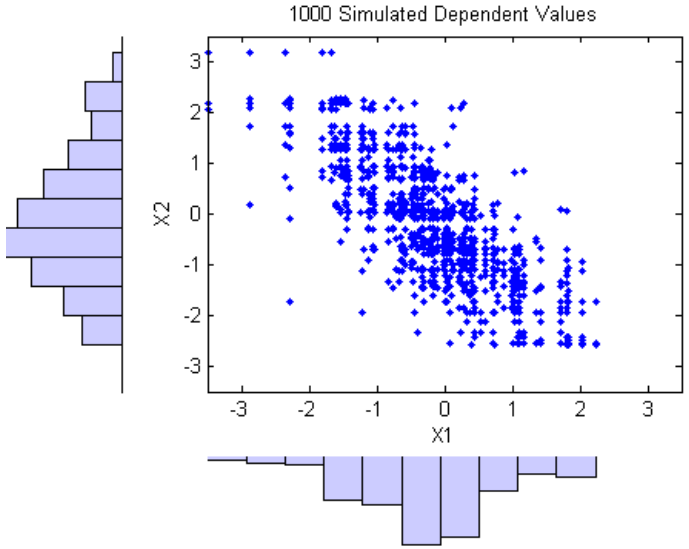
Dependent copula structure

$$f(x) = f_1(x_1) f_2(x_2) \ldots f_m(x_m) c(u_1, u_2, \ldots u_m)$$

Independent marginal distribution

u_i : *uniformly distributed random variables*

Example in 2d space:



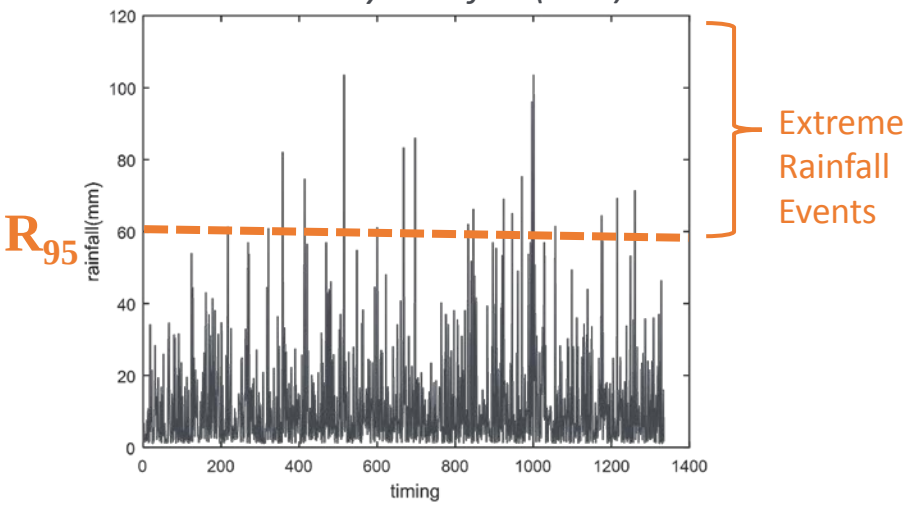
Steps:
Specify the copula family
Specify the rank correlation among variables
Specify the marginal distribution for each variable

Methodology:

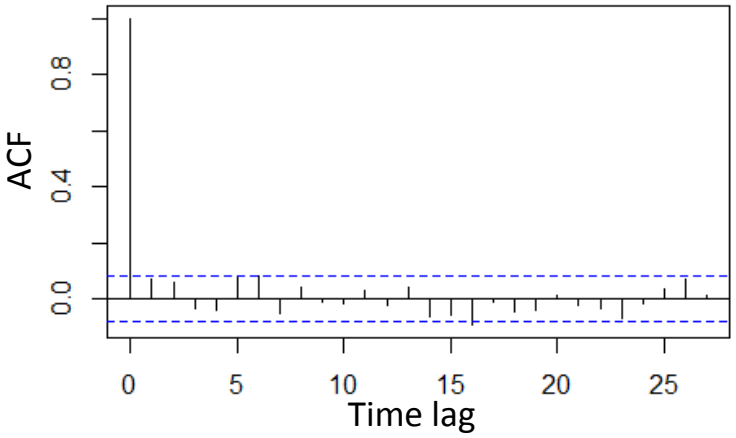
1- **Data:**
We used daily radar rainfall data from 2002-2015 (5112 days).
In NYC we have 102 grids for the land area.

2- **Extreme events:**
95%ile threshold is applied on each grid.
Result is 598 extreme event days.

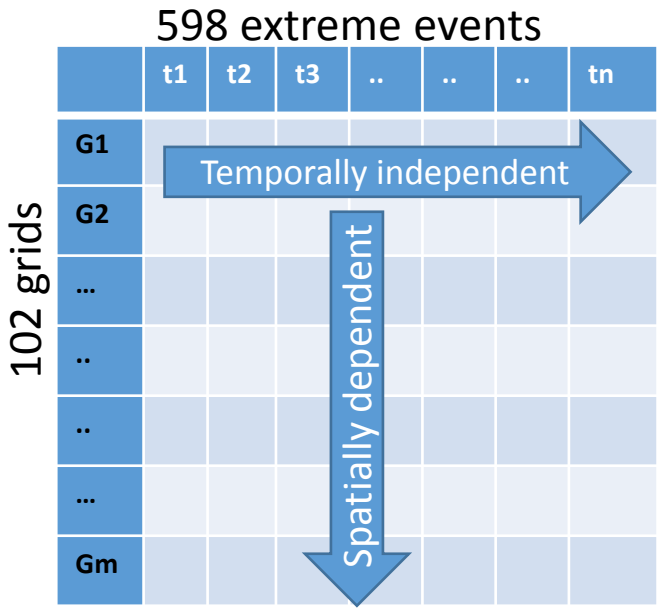
Time History Rainfall (mm)



Quantify temporal independence for a sample aird



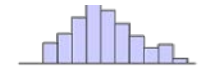
Model's Input Assumption:



Methodology:

3-Simulation

	t1	t2	t3	..	..	..	tn
G1	Rainfall time history for G1						
G2							
…							
..							
..							
…							
Gm	Rainfall time history for Gm						



…
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Independent marginal distribution — Dependent copula structure

$$f(x) = f_1(x_1) f_2(x_2) \dots f_m(x_m) c(u_1, u_2, \dots u_m)$$

Log-spline distribution is fitted to each grid's time history data

$$f_i(x_i) = e^{(\sum_{k=1}^{K} \beta_k g_k(x_i) - \beta_0)}$$

Apply empirical copula to each grid's time history data

$$C_n(u,v) = 1/n \sum_{i=1}^{n} 1\left(\frac{r_i}{n+1} \leqslant u, \frac{s_i}{n+1} \leqslant v\right)$$

a) Fit distribution to *f* and *c*

b) Add uncertainty by bootstrap resampling

c) Keep the dependencies by recording the ranks

Random sampling from data with replacement (bootstrap): **x'** + Corresponding rank **R'**

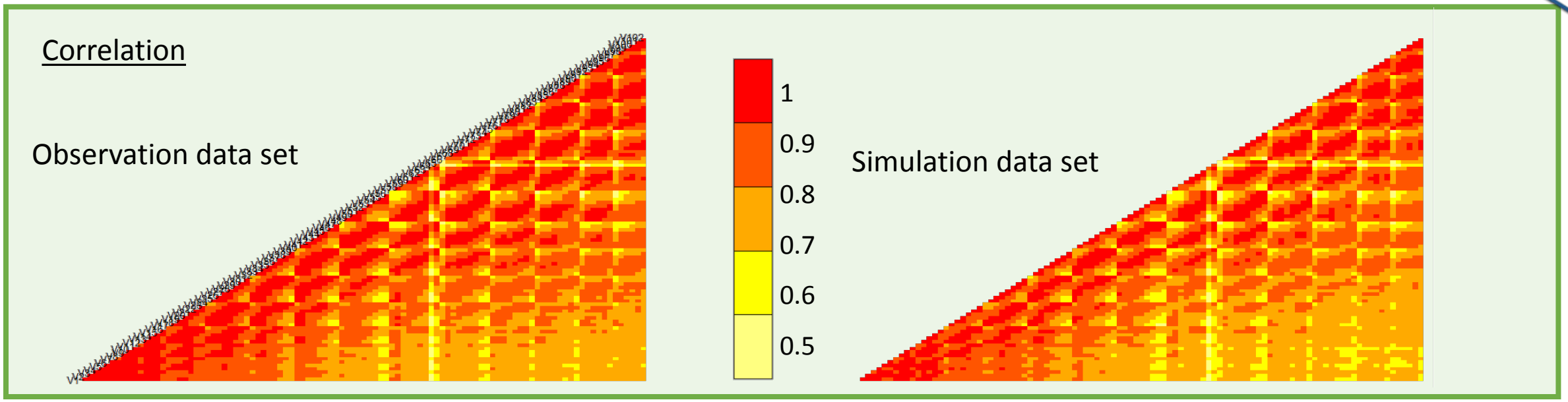
Random sampling from data with replacement (bootstrap): Rank function **Z'**

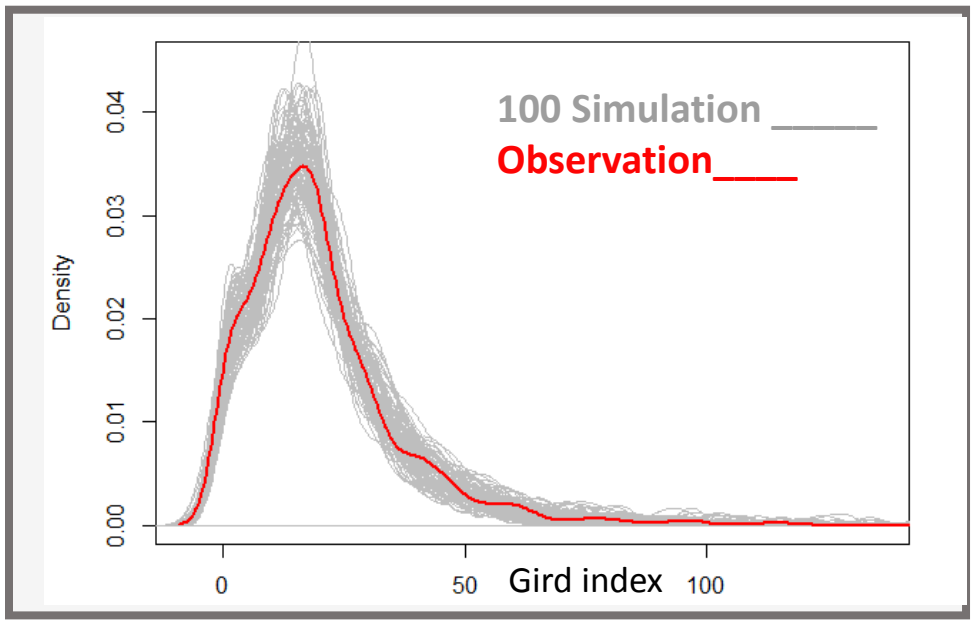
Simulated data: $w_{ij} = x'_{ij}\, \delta(R'_{ij} - z'_{ij})$

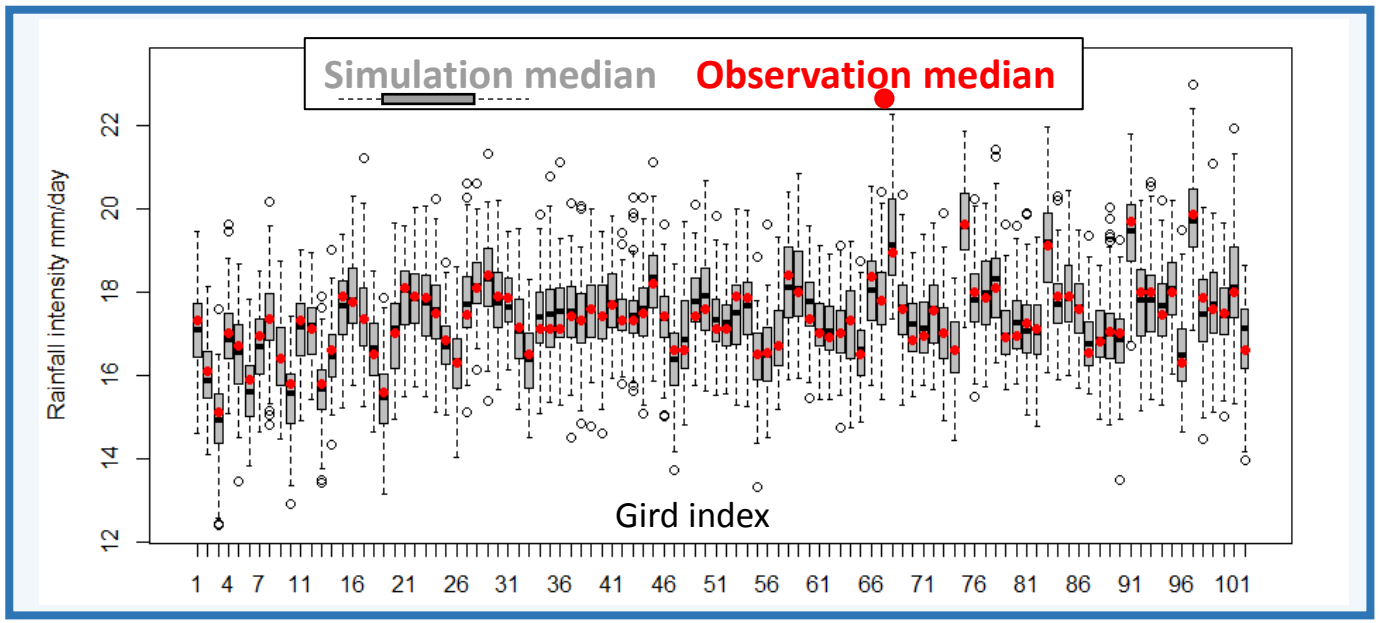
δ equals to1 if the argument is 0 and 0 else

100 simulation of 598 extreme events

Verify the Results of Simulation:

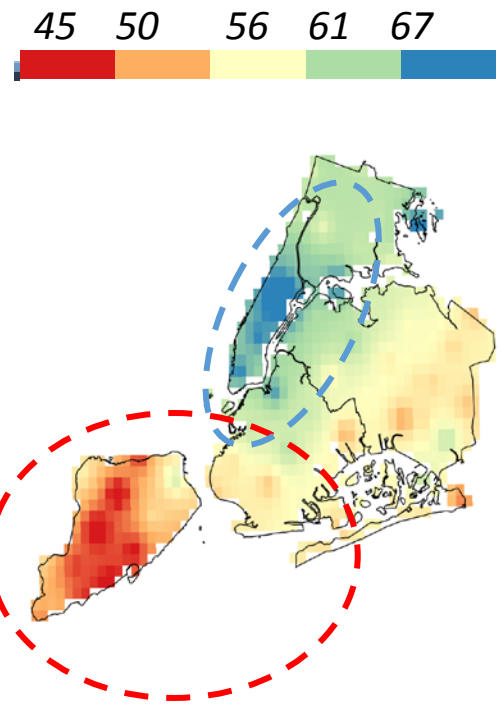




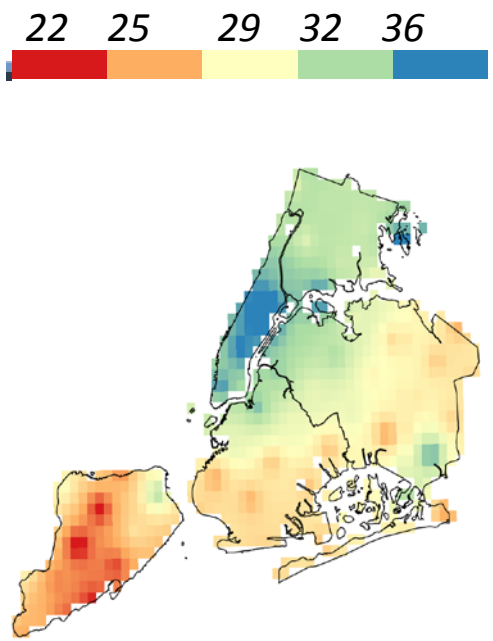


Results of Simulation:

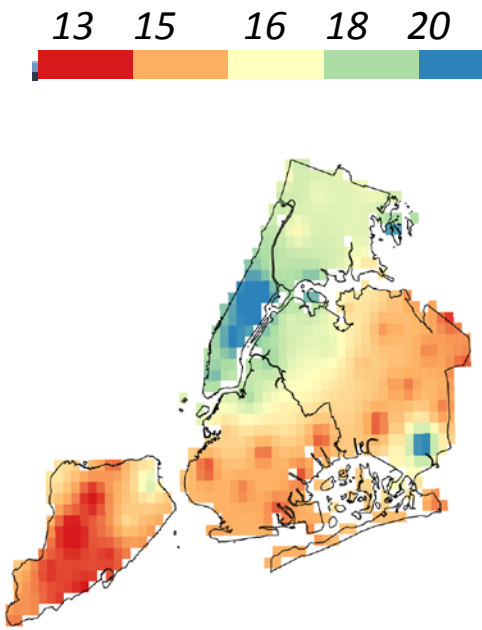
No. of events exceeding the threshold *(simulated data of 2002-2015, 14 yrs)*



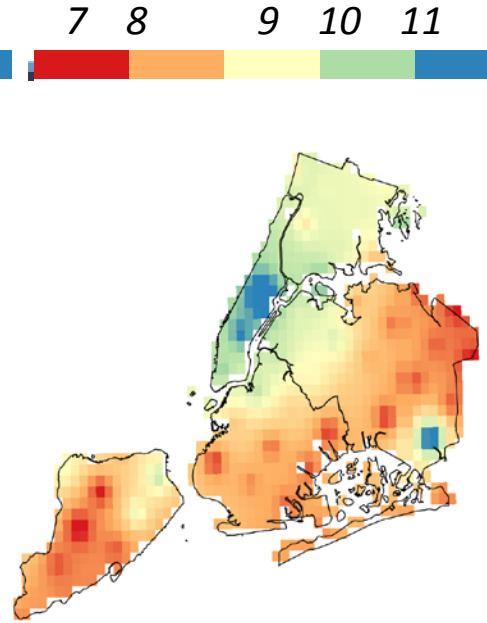
I=**95%ile** @ central park NYC 40mm/day*



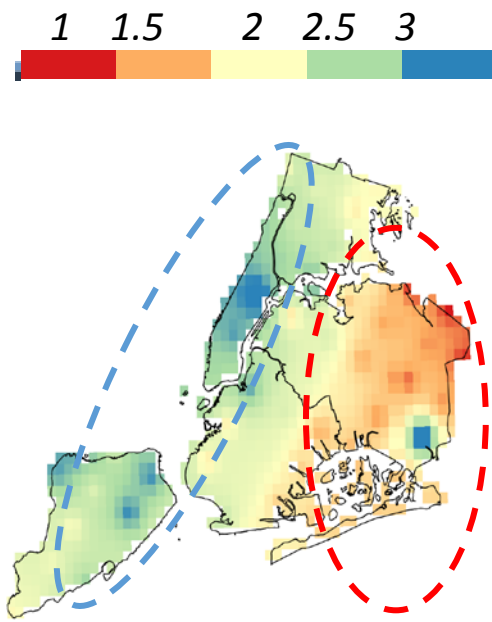
I=**97%ile** @ central park NYC 50mm/day*



I=**98%ile** @ central park NYC 60mm/day*



I=**99%ile** @ central park NYC 70mm/day*

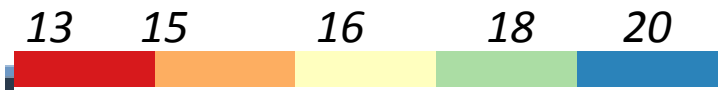


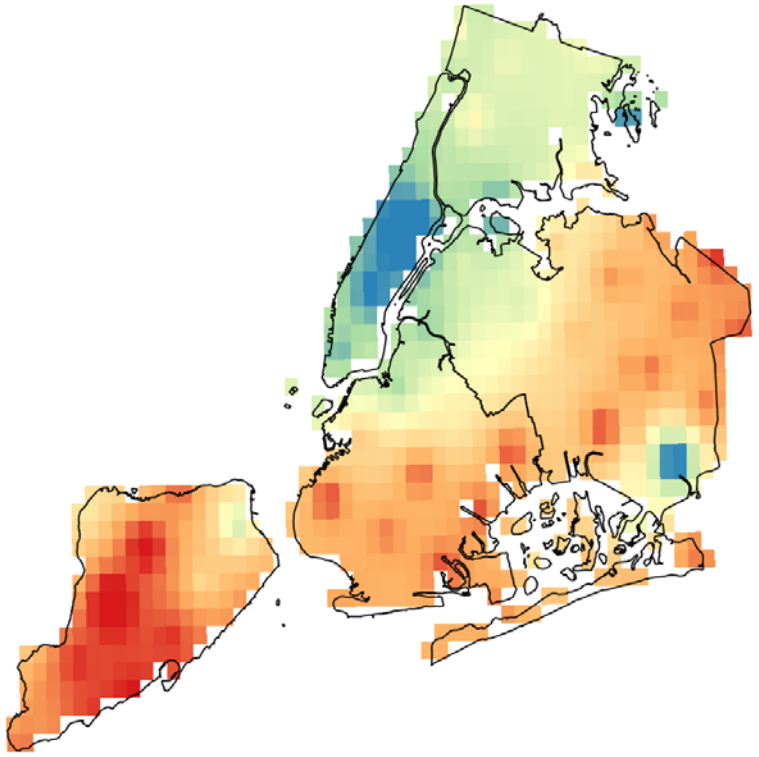
I=**99.5%ile** @ central park NYC 100mm/day*

Increase the rainfall threshold changes the hazardous region

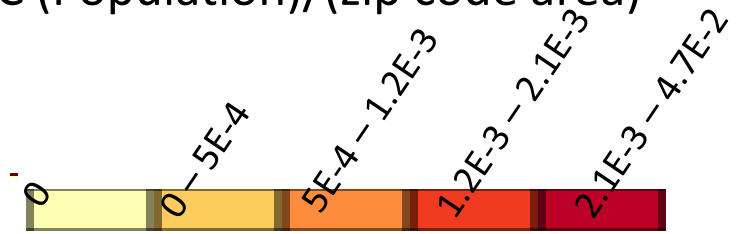
Comparing Simulation Results with NYCDEP Rainfall Design

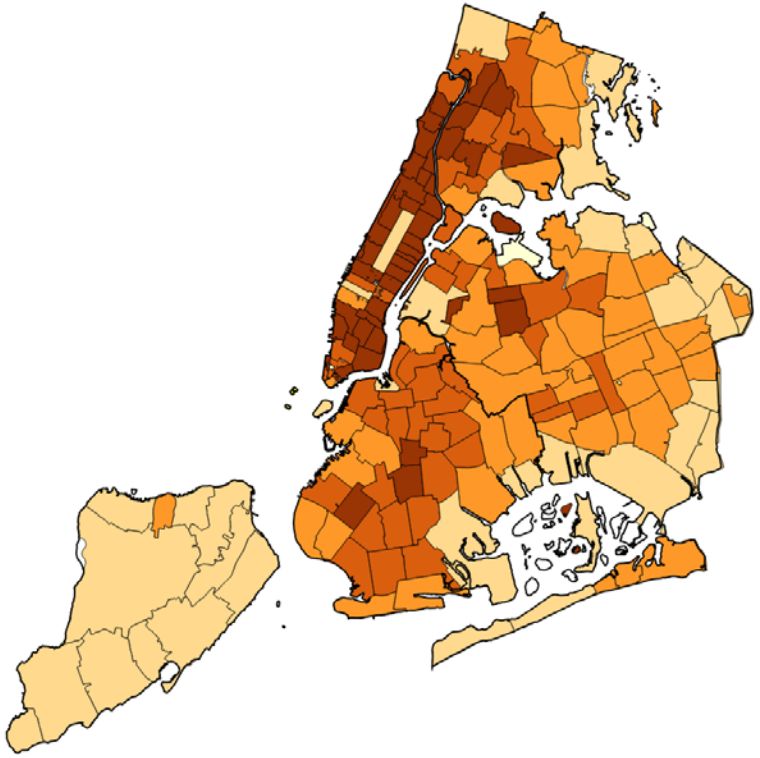
No. of events exceeding the 10-yr rainfall (2002-2015)





NYC (Population)/(zip code area)





I=**98%ile** @ central park NYC 60mm/day*

NYCDEP 10-year rainfall intensity ~ 60 mm/day i =140/(t+15)

Results of Simulation:

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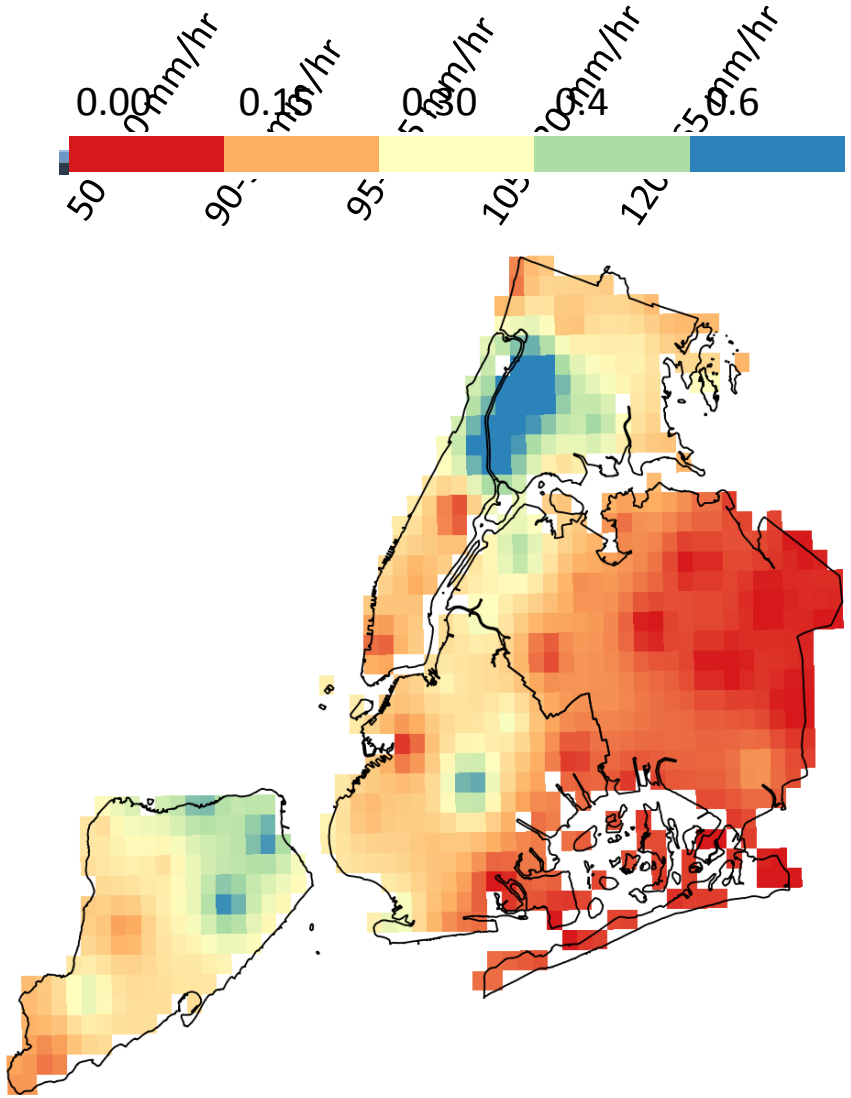
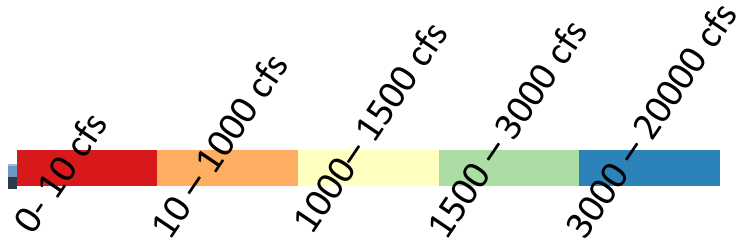
No. of events exceeding allowable intensity in NYC zip codes

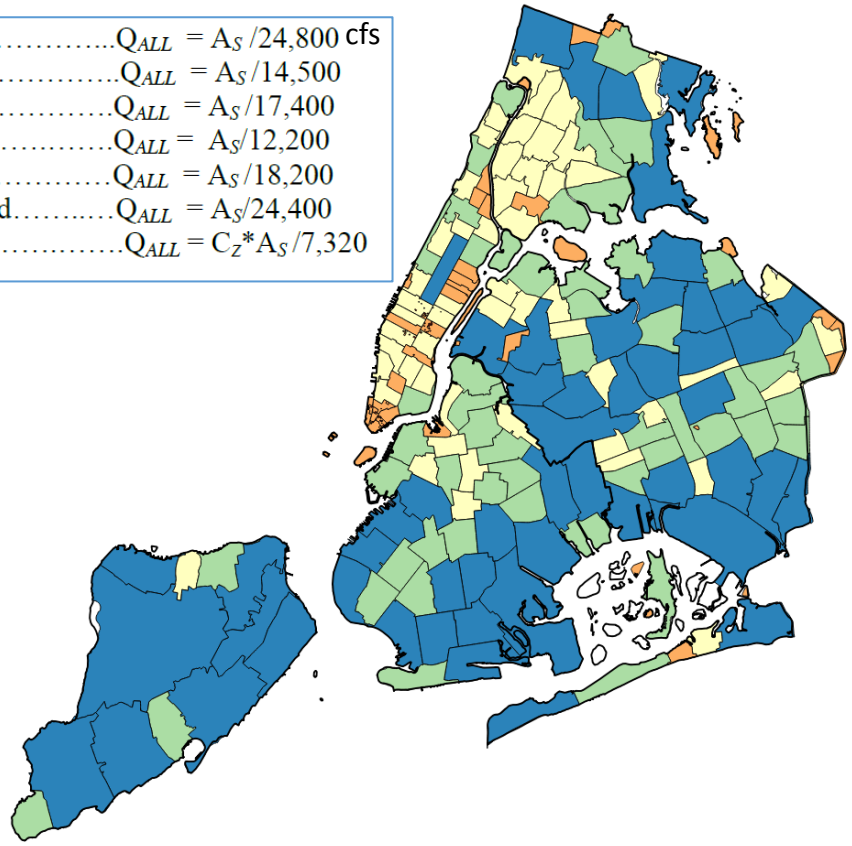


$I = Q/(CA)$

Allowable stormflow in NYC zip codes



Bronx-pre 1964	$Q_{ALL} = A_S/24{,}800$ cfs
Bronx-post 1964	$Q_{ALL} = A_S/14{,}500$
Brooklyn	$Q_{ALL} = A_S/17{,}400$
Manhattan	$Q_{ALL} = A_S/12{,}200$
Queens	$Q_{ALL} = A_S/18{,}200$
Staten Island Combined	$Q_{ALL} = A_S/24{,}400$
Staten Island Storm	$Q_{ALL} = C_Z * A_S/7{,}320$



Summary

- Using Copula we were able to simulate spatial dependent storm field with corresponding uncertainty.
- Having high resolution simulated data, we can have a realistic comparison and analysis of the risk of extreme rainfall at the city scale.
- Comparing with NYCDEP intensity, we have areas with high frequency of extreme rainfall. Also, allowable storm flow could be design more efficient.
- Next level of this study is to simulate the trend of extreme rainfall beside the spatial dependence structure.

Acknowledgement

NOAA STAR CENTER FOR SATELLITE APPLICATIONS AND RESEARCH
CCRUN
cics-md Cooperative Institute for Climate & Satellites UNIVERSITY OF MARYLAND
PSC-CUNY WELFARE FUND
NATIONAL SEVERE STORMS LABORATORY
University Transportation Research Center
NOAA | CREST
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