Compounding Effects of Ocean and Fluvial Flooding in a Warming Climate

Amir AghaKouchak,

University of California, Irvine

Hamed Moftakhari, Gianfausto Salvadori, Brett Sanders, Richard Matthew

Email: amir.a@uci.edu

: @AmirAghaKouchak

Compound Extreme Events

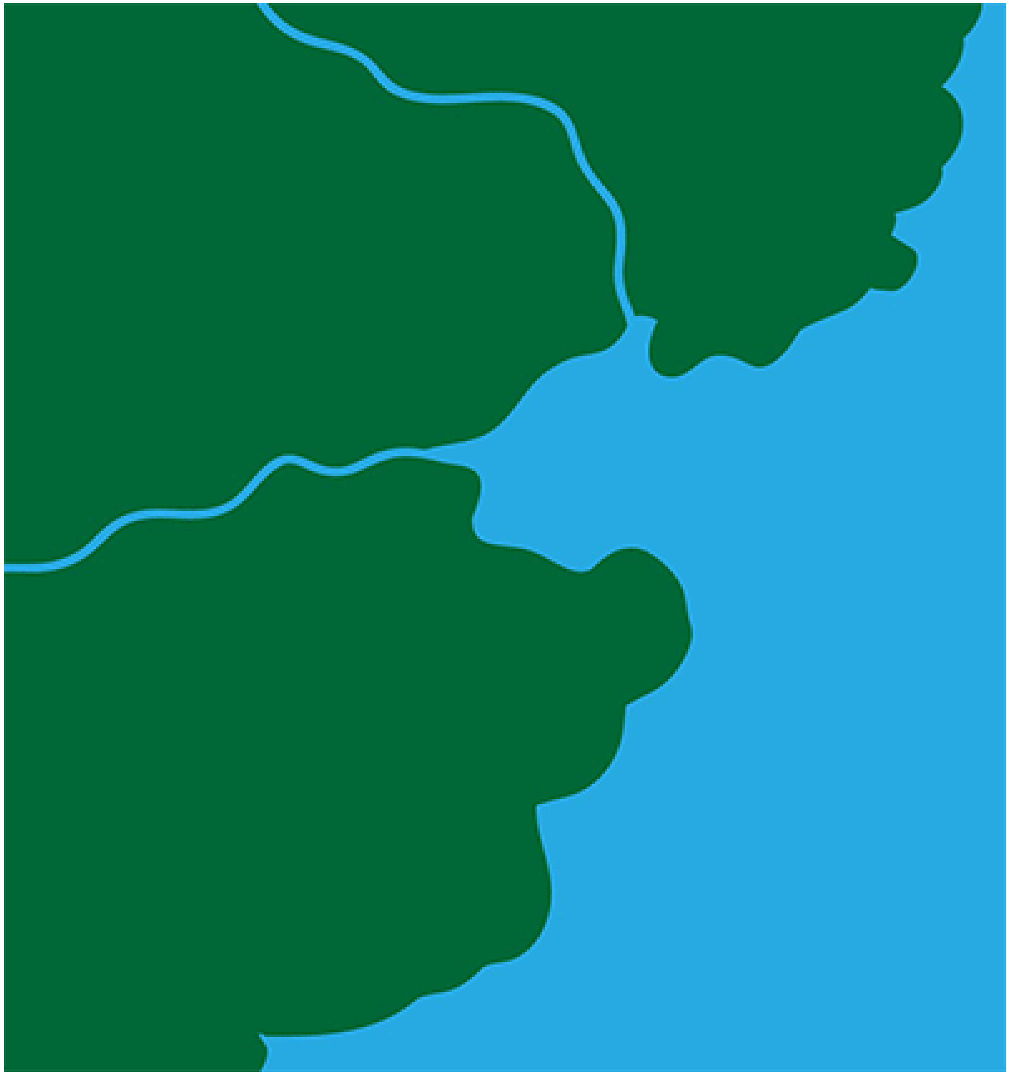
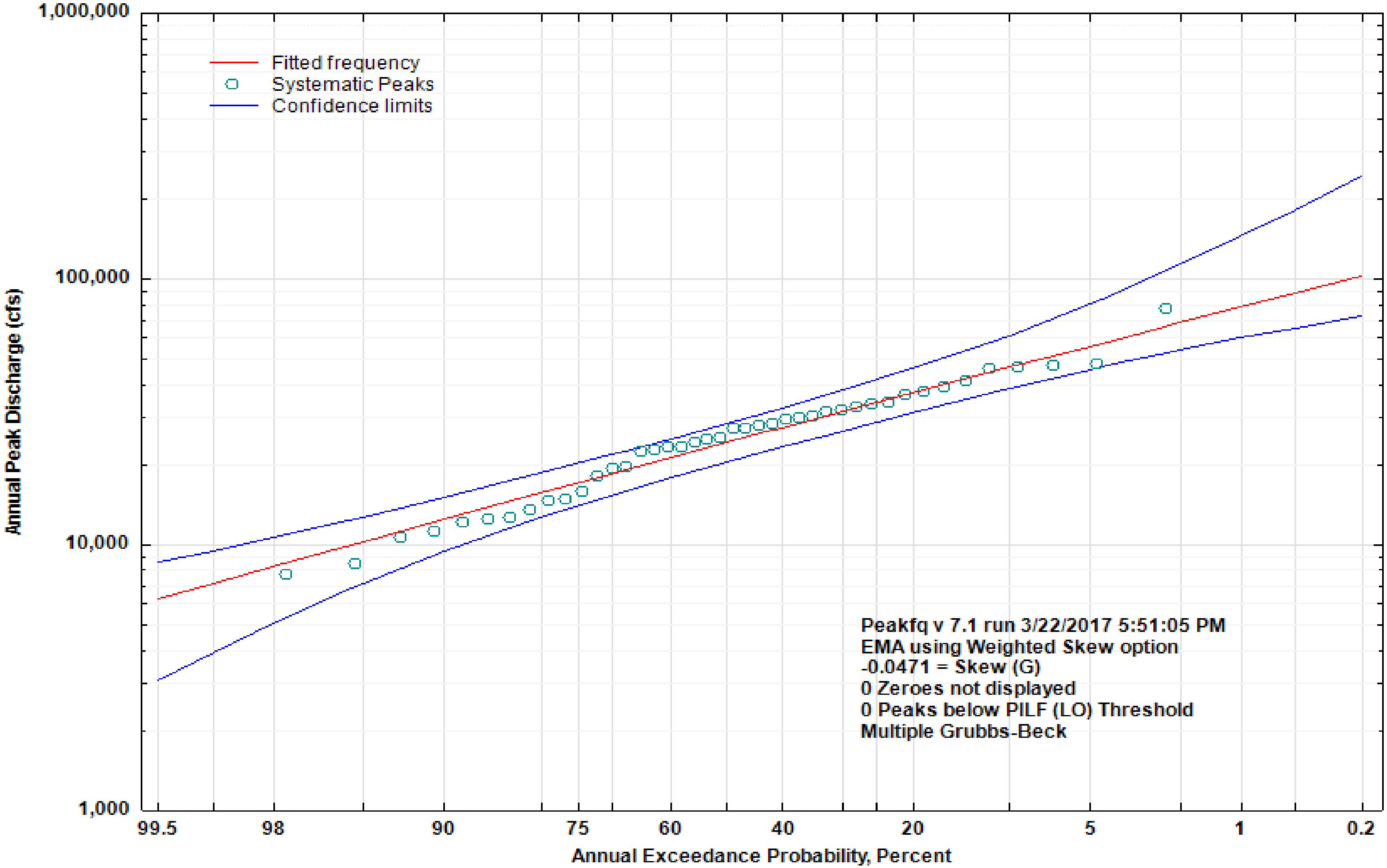


Image Credit: NASA/JPL

Compound Extreme Events



Compound Extreme Events

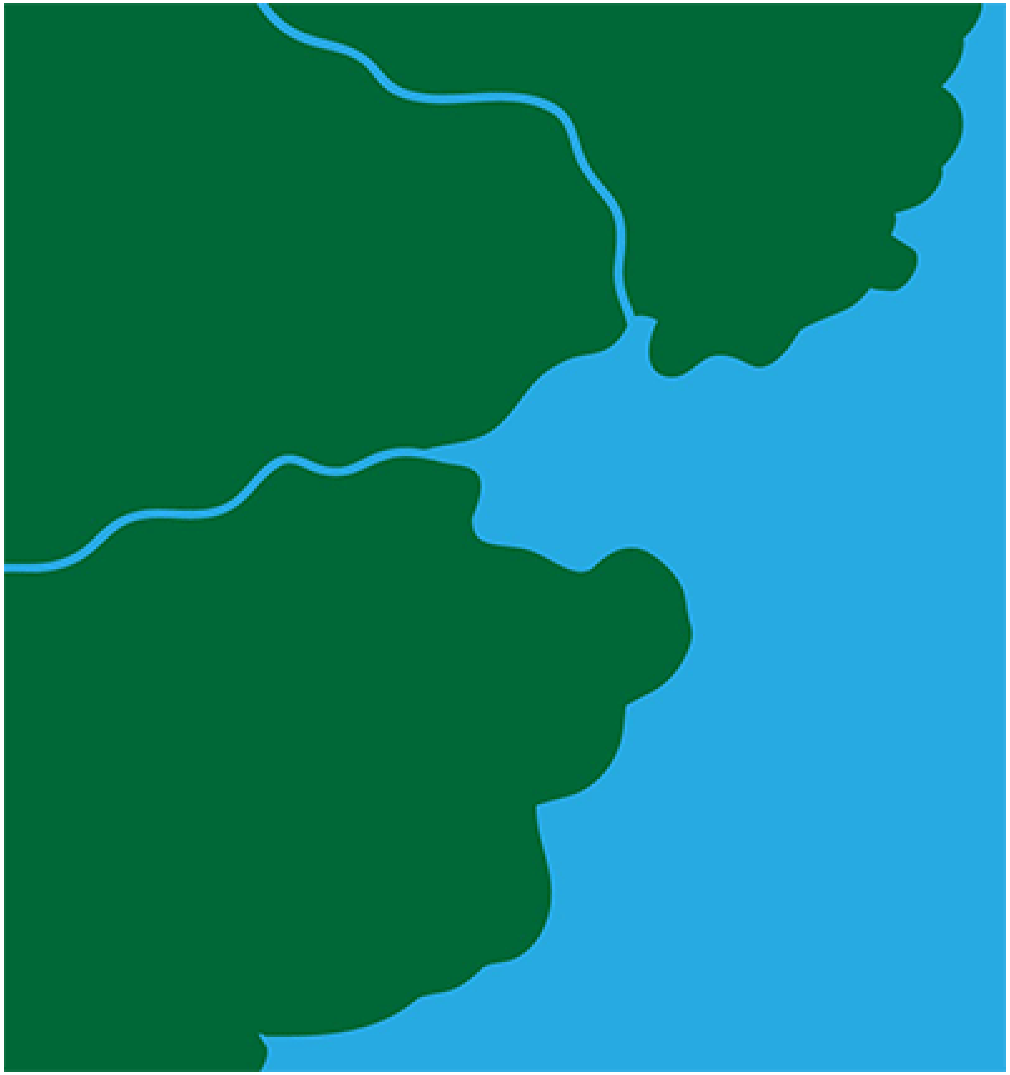
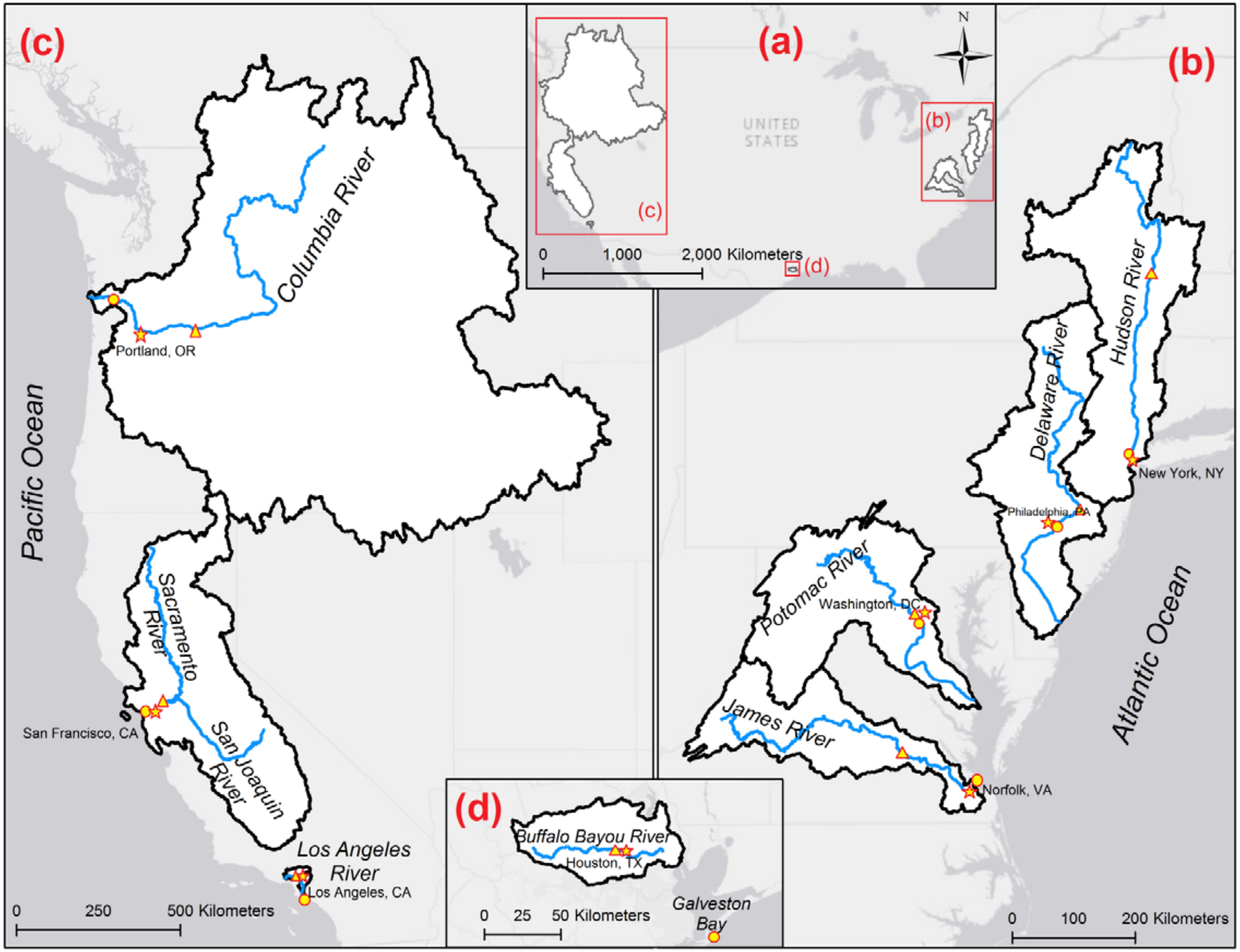


Image Credit: NASA/JPL

Compound Extreme Events

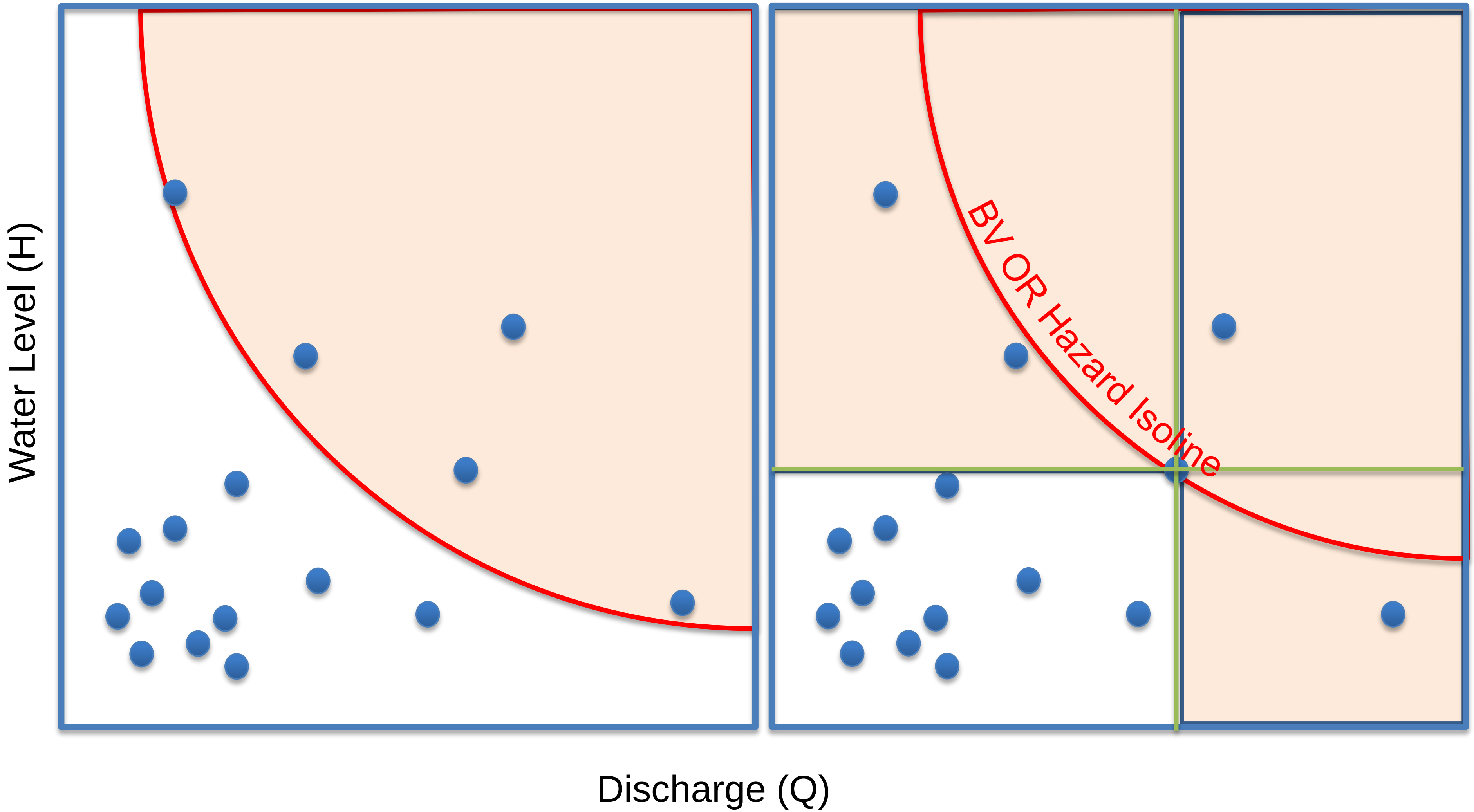
- ***Two or more extreme events occurring simultaneously or successively***
- ***Combinations of extreme events with underlying conditions that amplify the impact of the events***
- ***Combinations of events that are not themselves extremes but lead to an extreme event or impact when combined.***
- ***Consecutive inter-dependent events that do not occur at the same time, but they have compounding impacts.***

Compound Extreme Events



Compound Extreme Events

$$\alpha_x^{\vee} = P(X \in S_x^{\vee}) = 1 - C_X(F_1(x_1), F_2(x_2))$$



Moftakhari H.M., Salvadori G., AghaKouchak A., Sanders, B.F., Matthew, R.A., 2017, Compounding Effects of Sea Level Rise and Fluvial Flooding, *Proceedings of the National Academy of Sciences*, doi: 10.1073/pnas.1620325114.

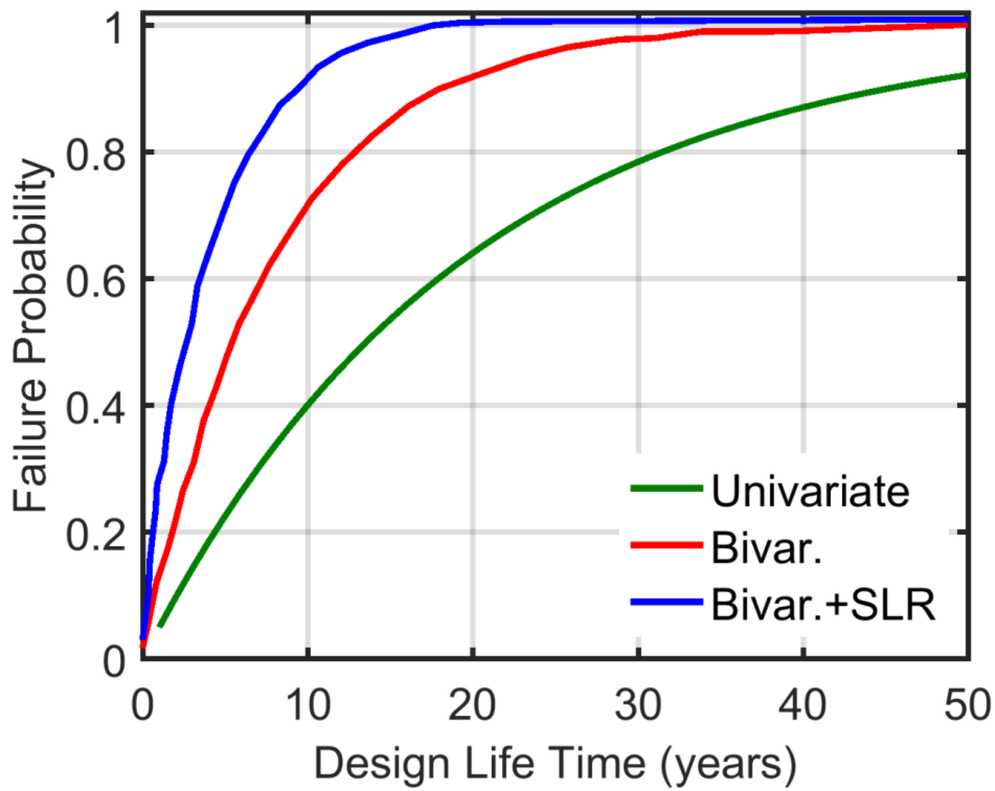
For a given design life time of T the failure probability ($\check{P}_T$) is calculated as

Univariate

$$\check{P}_T = 1 - (1-p)^T$$

Multivariate

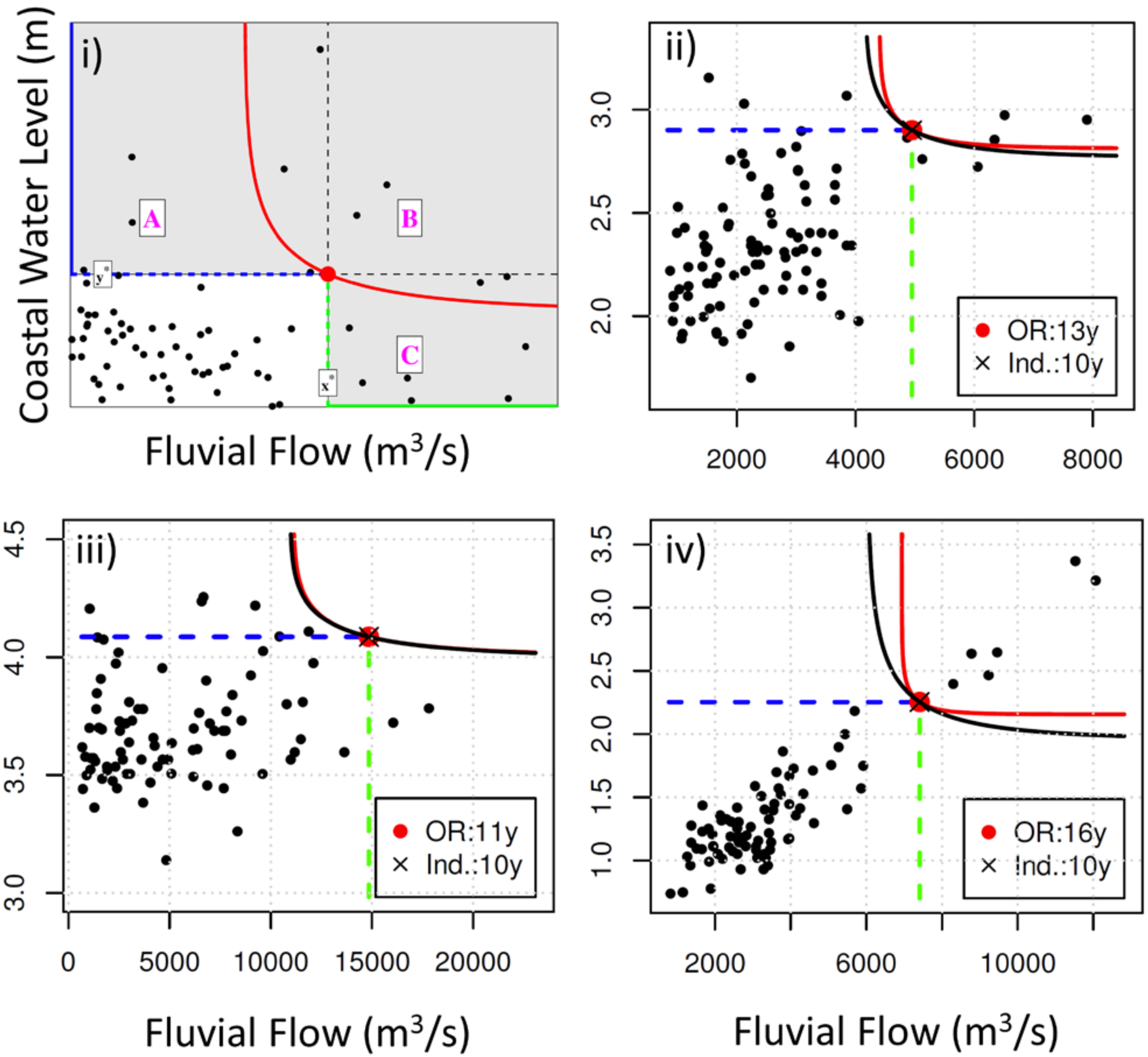
$$\check{P}_T = 1 - P\left(X_1 \in S_1^C, \ldots, X_T \in S_T^C\right)$$
$$= 1 - \left(C_X(F_1(\tilde{x}_1), F_2(\tilde{x}_2))\right)^T$$



Compounding effects of sea level rise and fluvial flooding

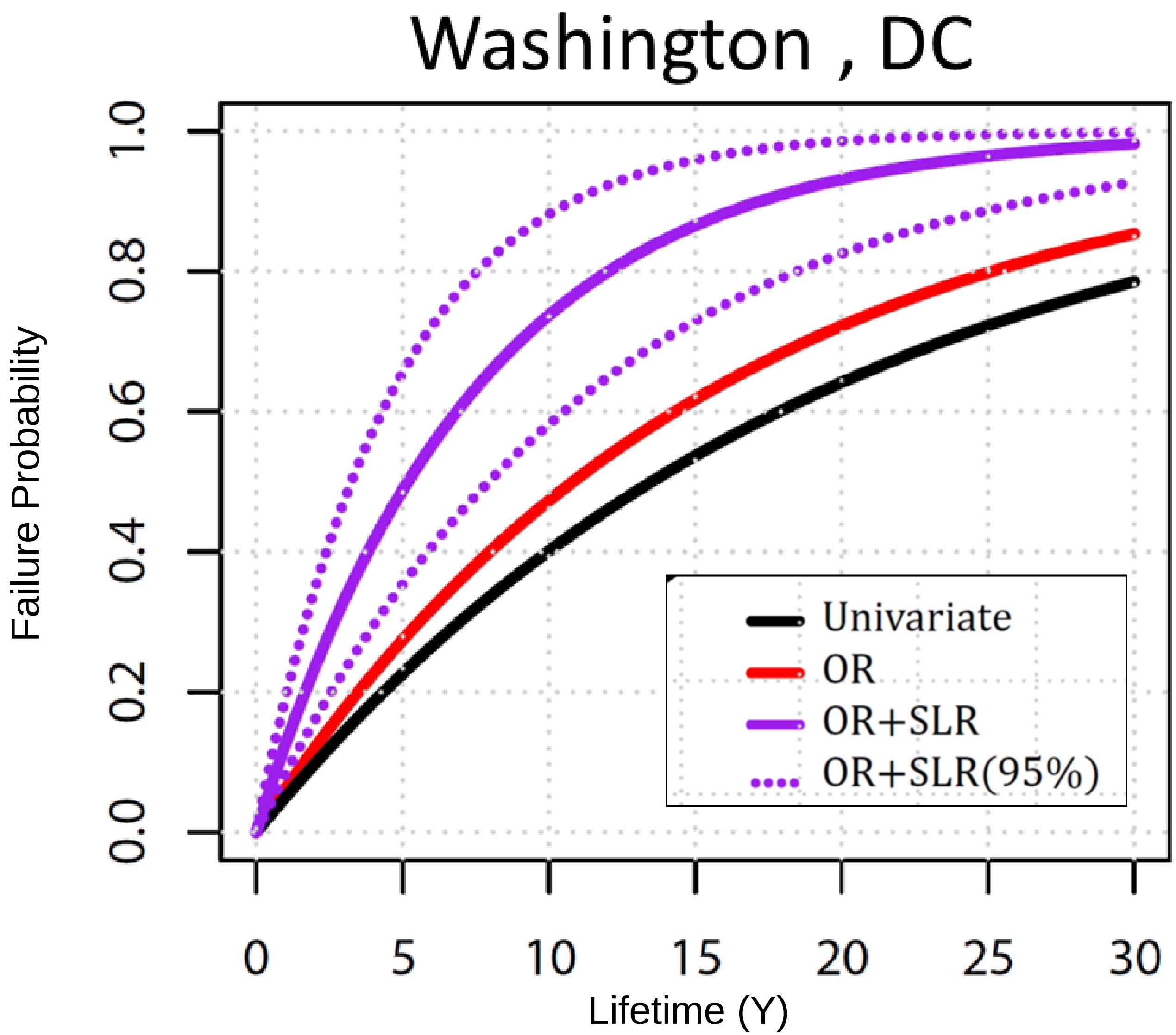
Hamed R. Moftakhari[a], Gianfausto Salvadori[b], Amir AghaKouchak[a,c,1], Brett F. Sanders[a,d], and Richard A. Matthew[d,e]

Compound Extreme Events

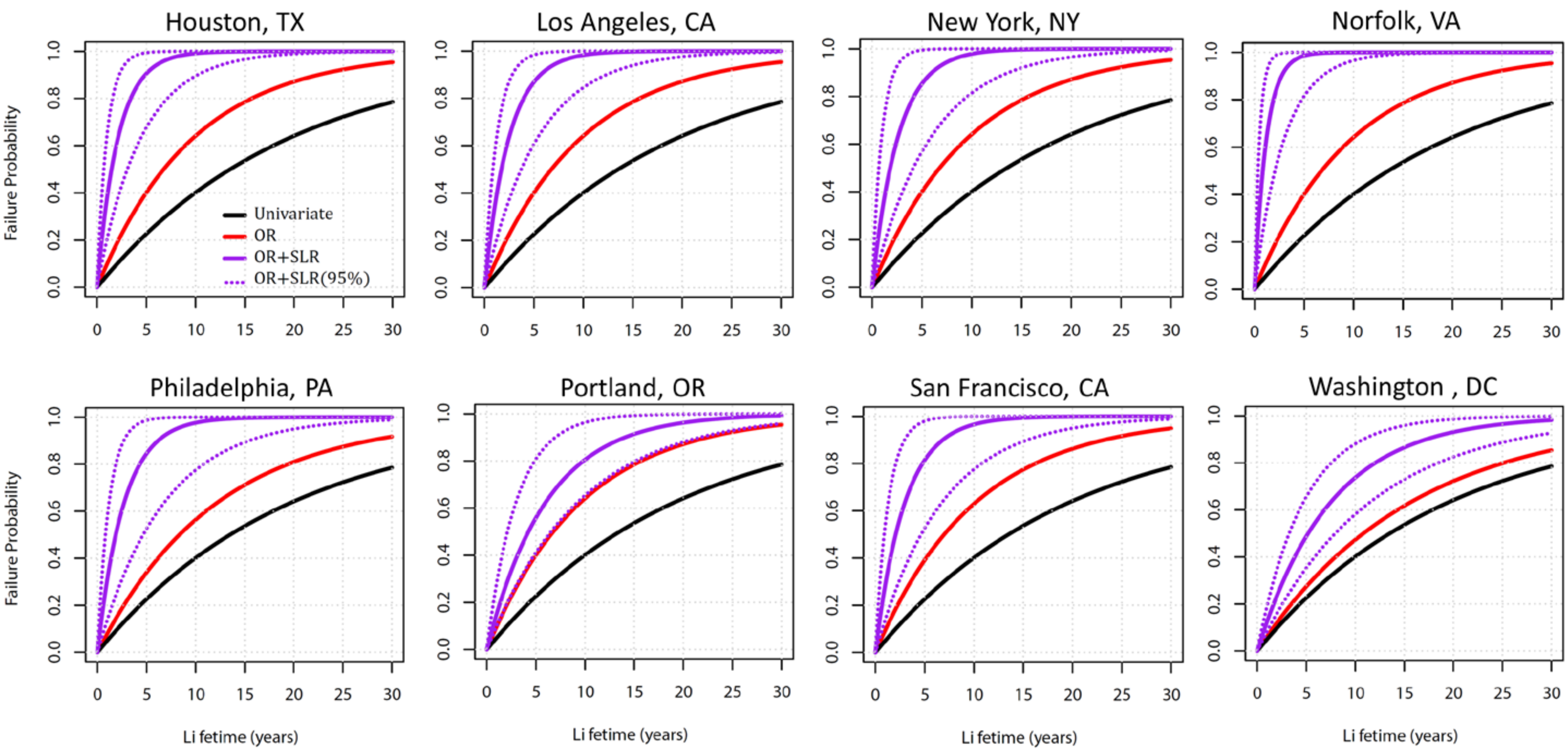


i) Illustration of the univariate and bivariate Hazard Scenarios. The black circles represent observed bivariate occurrences, the red circle is the reference occurrence $z^* = (x^*, y^*)$, the red line is the isoline of F_{XY} crossing z^*, with level $F_{XY}(x^*, y^*) \leq min\{F_X(x^*), F_Y(y^*)\}$, and the black line is the isoline of F_{XY} crossing z^*, under the simplifying assumption of independence between Fluvial Flow and Coastal WL. The hazardous regions A, B, and C are indicated as dashed areas. The estimates of the bivariate OR RP's associated with the occurrence z^* are indicated in the legends for Philadelphia, PA (Figure 1ii), San Francisco, CA (Figure 1iii), and Washington, DC (Figure 1iv).

Compound Extreme Events - Failure Probability 2030 RCP4.5

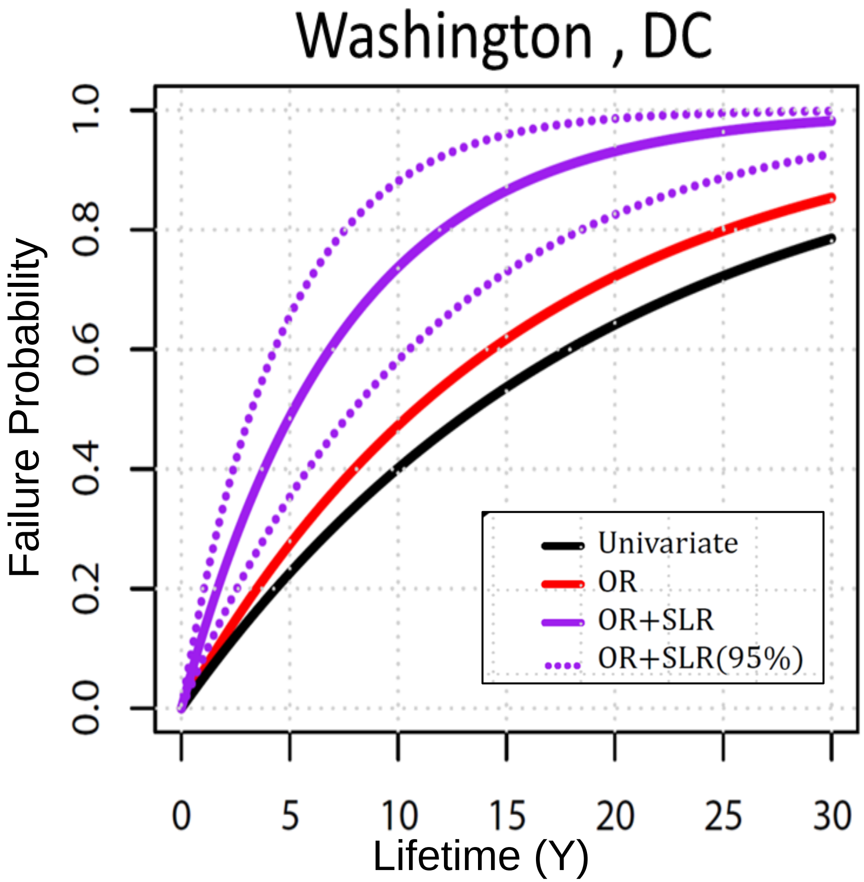


Compound Extreme Events



Estimated failure probability for a temporal horizon of 30 years. The solid black and red curves show, respectively, the estimated failure probability computed based on the univariate and bivariate OR hazard scenarios, according to the presently observed climate conditions. The solid and dashed purple curves show the estimated probability of failure using a bivariate OR approach and an associated 95% confidence band considering the projected SLR for 2030 under RCP 4.5.

Summary



Current coastal flood frequency analysis methods do not consider the compounding effects of ocean and fluvial flooding.

A univariate approach in risk assessment may lead to underestimation of flood risk.

Research Gaps:

Lack of theoretical frameworks for, change detection, frequency analysis and risk assessment of compound extremes.

- **Detecting changes in frequency and distribution of compound extremes (drought-heatwaves and heatwaves-human mortality)**
- **Multivariate frequency analysis and risk assessment**

Understanding and modeling the changing nature of human activities and their interactions with compound events.

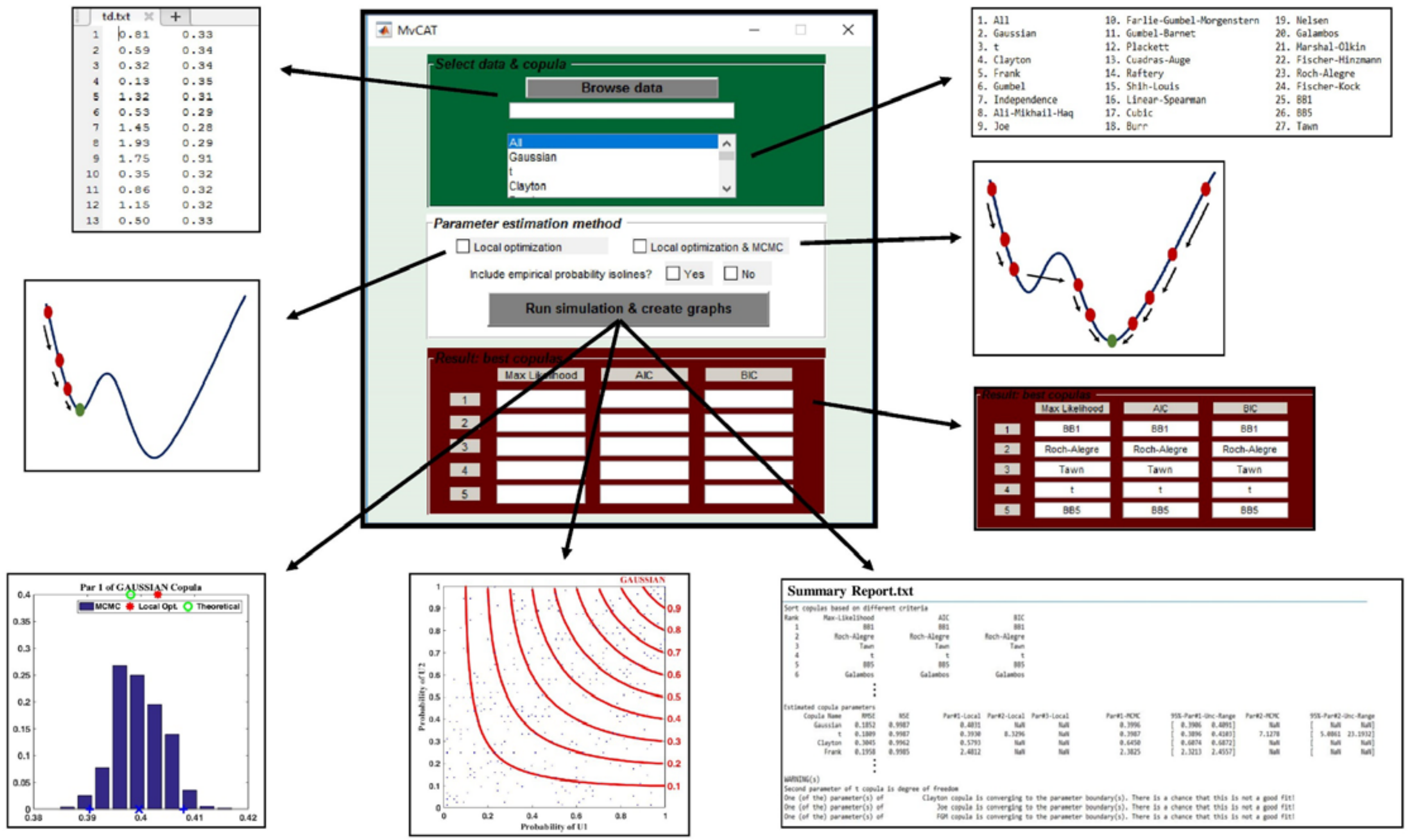
- **Compounding effects of different urbanization and sea level rise and the corresponding impacts in coastal areas**

MvCAT is freely available here:

http://amir.eng.uci.edu/software.php

Sadegh, M., Ragno, E. and AghaKouchak, A. (2017), Multivariate Copula Analysis Toolbox (MvCAT): Describing dependence and underlying uncertainty using a Bayesian framework. *Water Resources Research*, 53, doi:10.1002/2016WR020242

Multivariate Copula Analysis Toolbox (MvCAT)



Multivariate Copula Analysis Toolbox (MvCAT)

Moji Sadegh

Elisa Ragno

AGU PUBLICATIONS

Water Resources Research

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10.1002/2016WR020242

Multivariate Copula Analysis Toolbox (MvCAT): Describing dependence and underlying uncertainty using a Bayesian framework

Mojtaba Sadegh[1,2], Elisa Ragno[1], and Amir AghaKouchak[1,3]

Key Points:

- Copulas are a powerful tool to

Questions?

Amir AghaKouchak

Email: amir.a@uci.edu
Twitter: @AmirAghaKouchak

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