Compound Flood Risk Assessment

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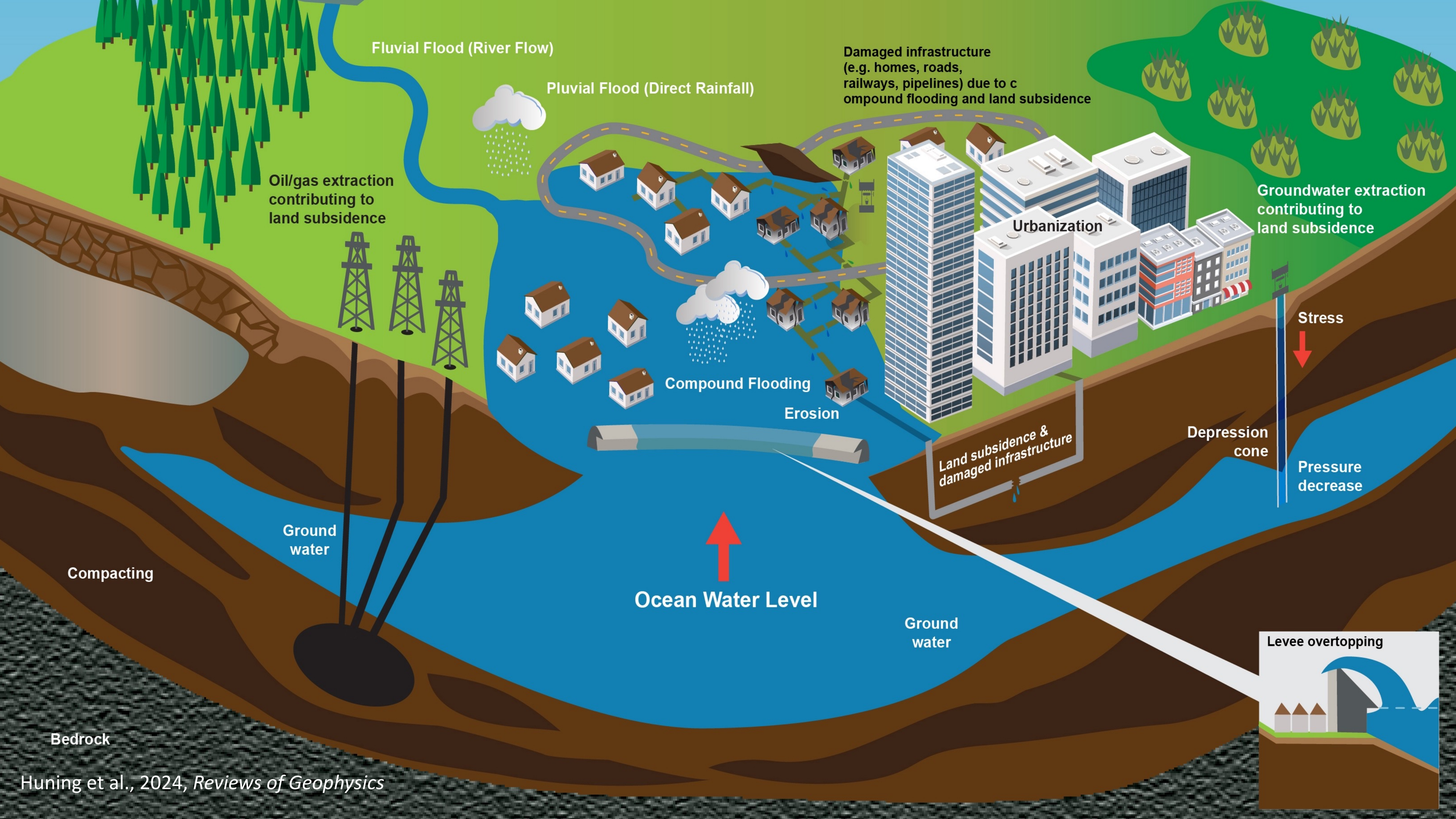
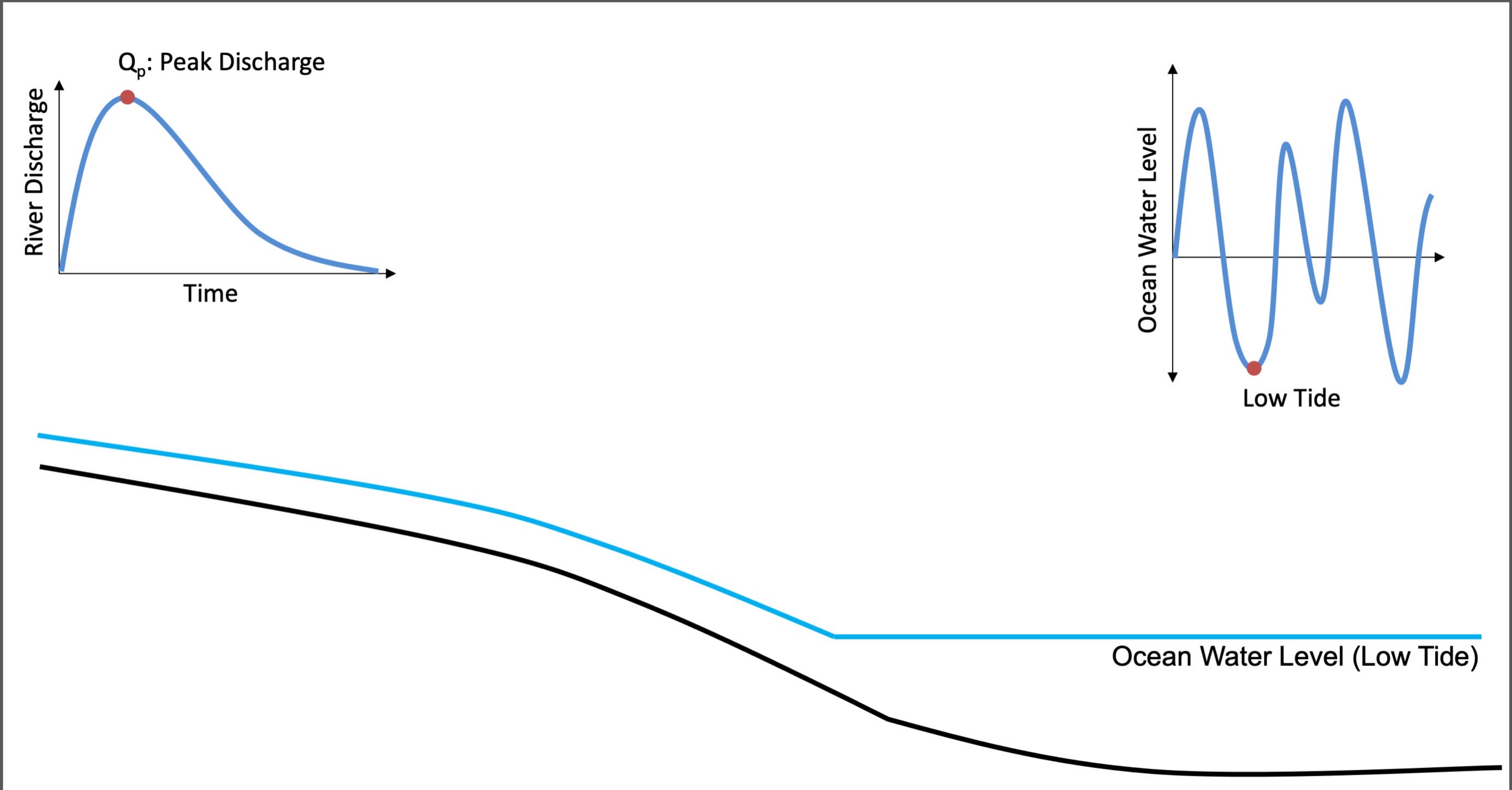
Coastal Flooding

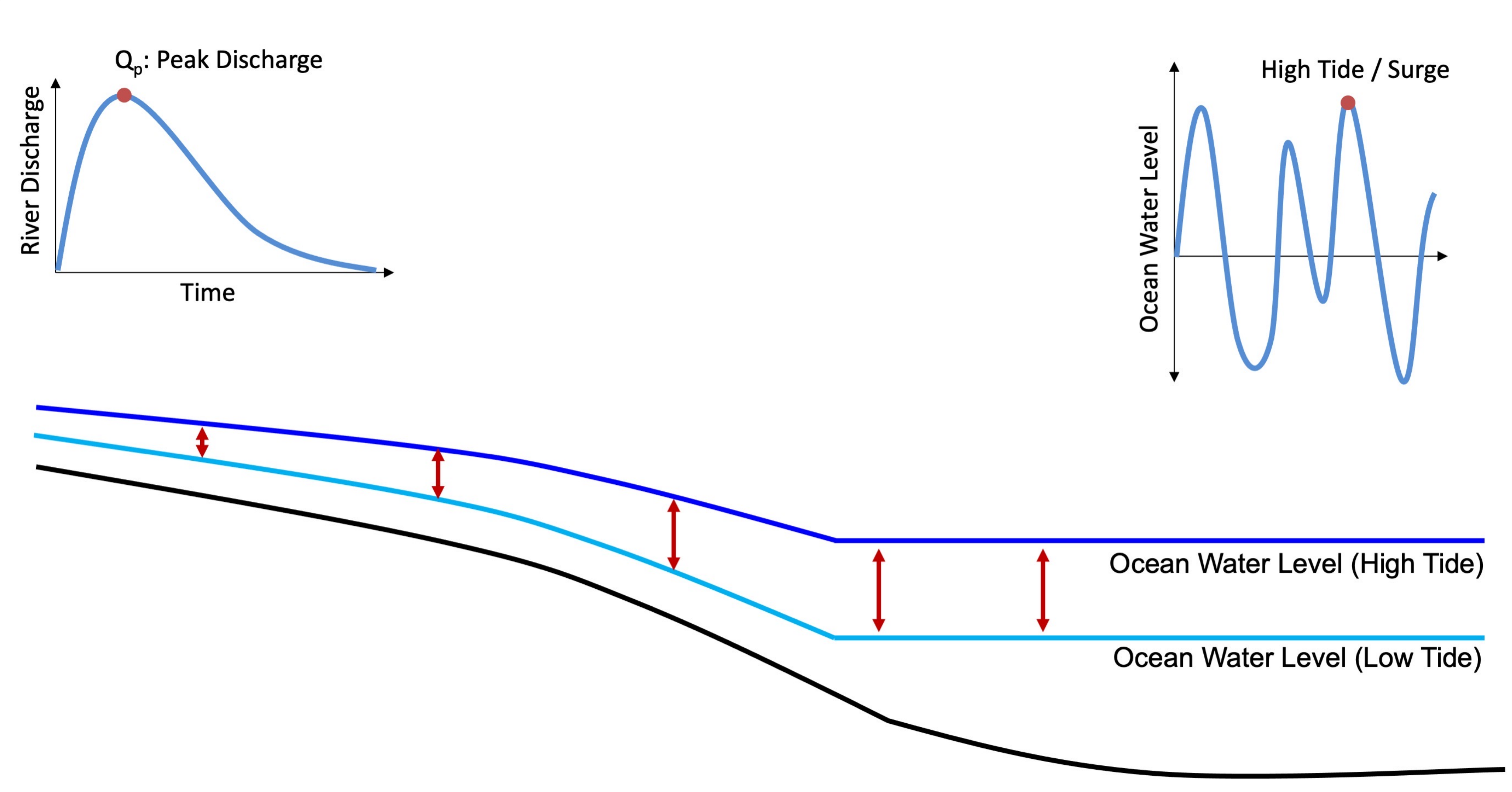
Compound Ocean-Fluvial Flooding

Compound Ocean-Fluvial (terrestrial)-Pluvial (local rain) Flooding

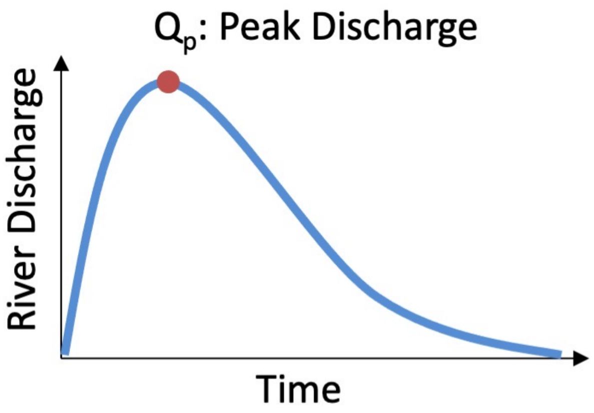


Huning et al., 2024, *Reviews of Geophysics*


Q_p: Peak Discharge
River Discharge
Time
Ocean Water Level
Low Tide
Ocean Water Level (Low Tide)



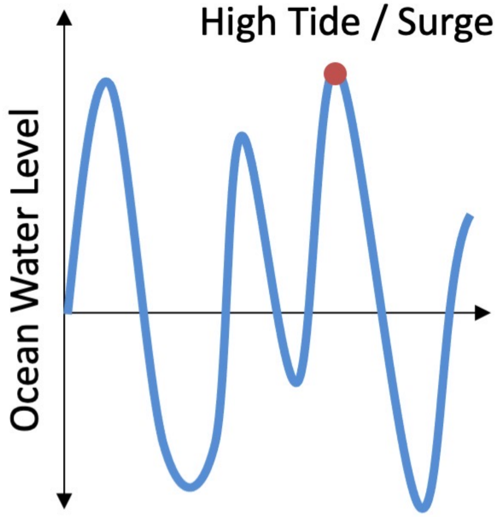
Q_p: Peak Discharge
River Discharge
Time
High Tide / Surge
Ocean Water Level
Ocean Water Level (High Tide)
Ocean Water Level (Low Tide)

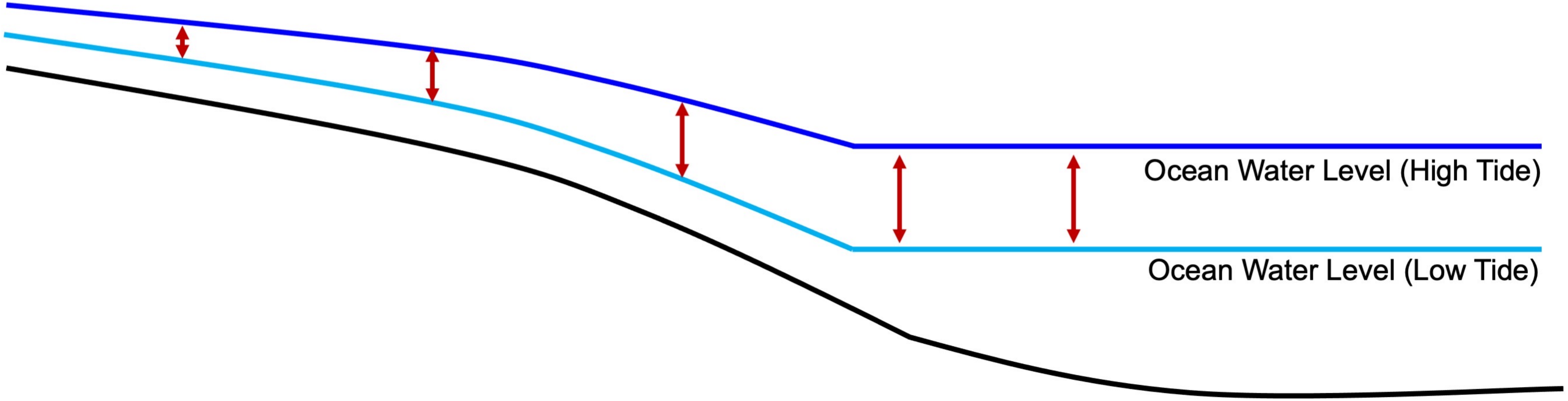


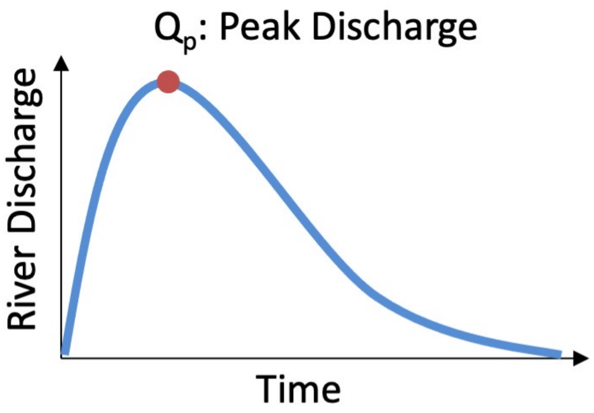
Univariate

$$p_F = 1 - (1 - p)^T$$

T: lifetime (years)
p: exceedance probability







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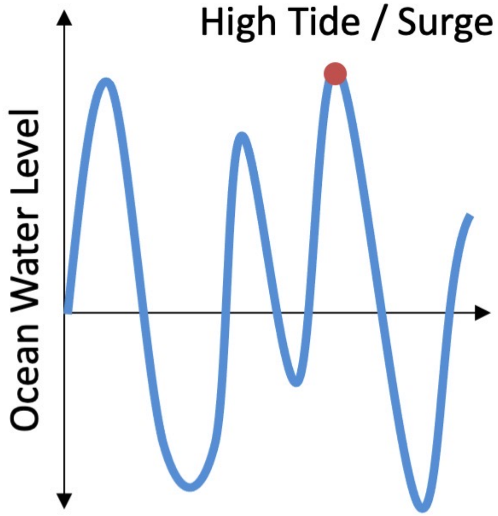
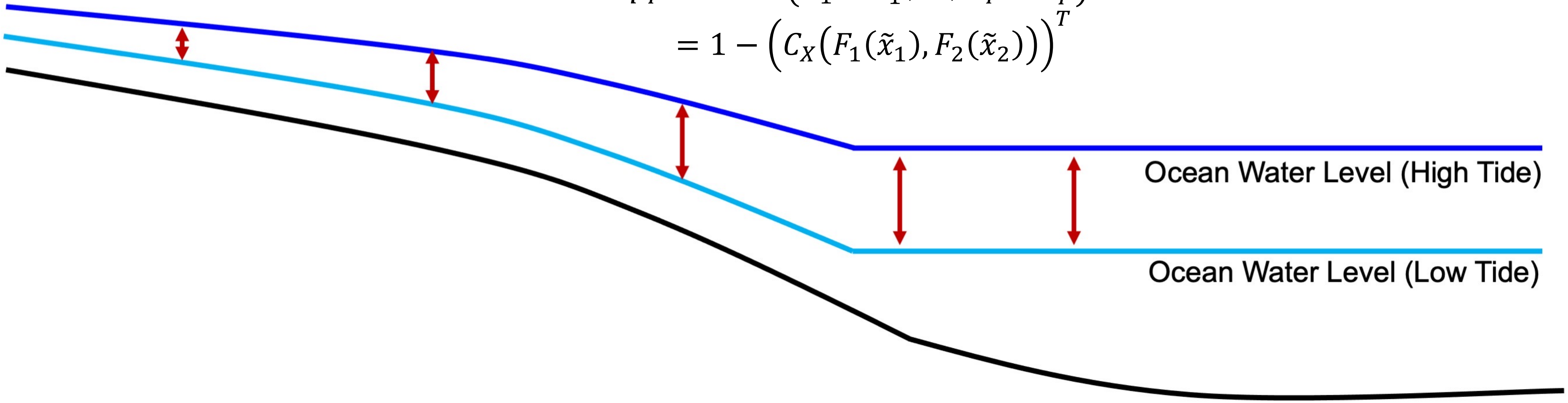
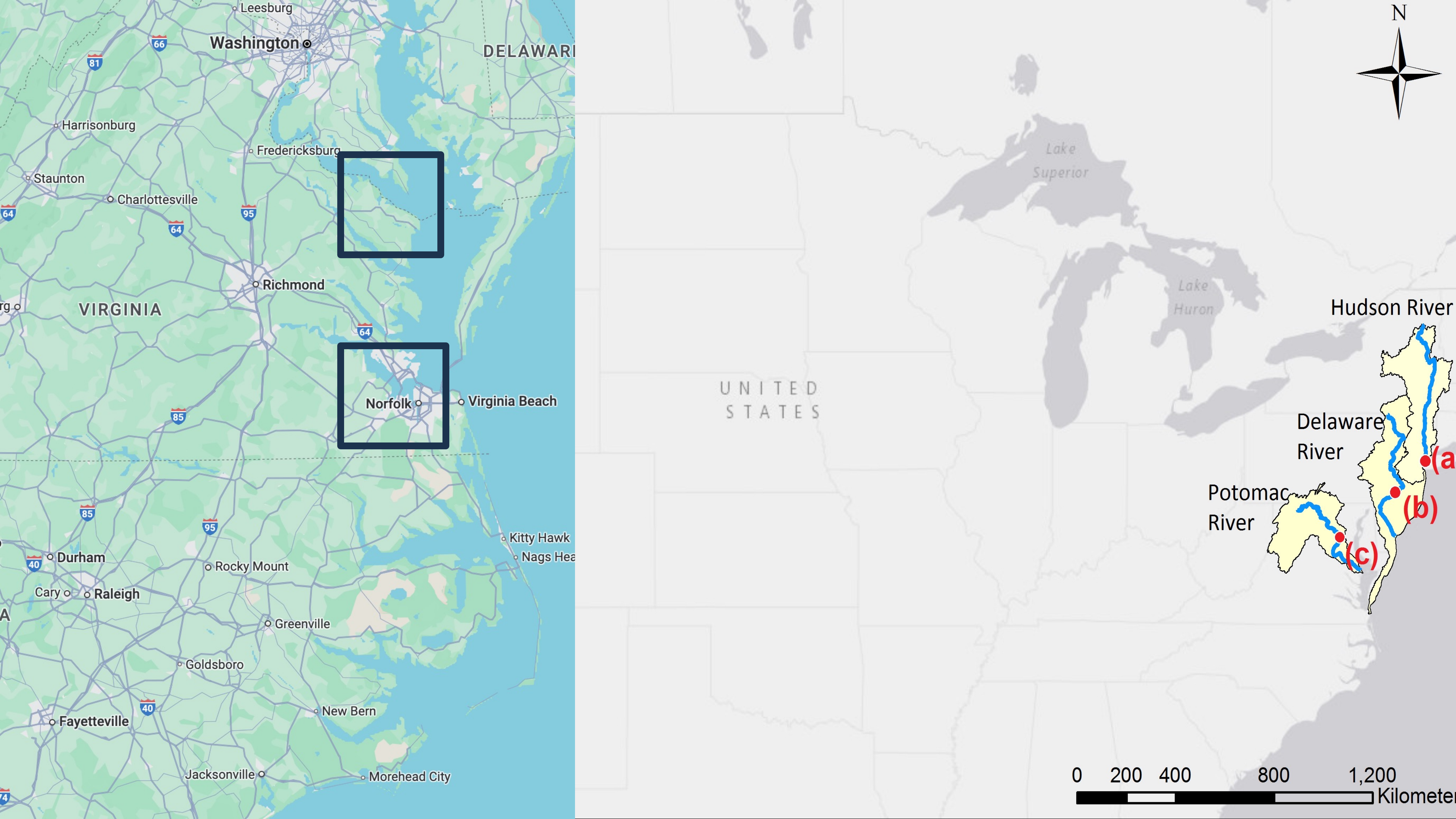


Multivariate

(Moftakhari, et al., 2017, *PNAS*)

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




Leesburg
Washington
DELAWARE
Harrisonburg
Fredericksburg
Staunton
Charlottesville
Richmond
VIRGINIA
Norfolk
Virginia Beach
Kitty Hawk
Durham
Rocky Mount
Cary
Raleigh
Greenville
Goldsboro
New Bern
Fayetteville
Jacksonville
Morehead City
66
81
64
95
85
40
N
Lake Superior
Lake Huron
UNITED STATES
Hudson River
Delaware River
Potomac River
(a)
(b)
(c)
0 200 400 800 1,200
Kilometer

For a given system/infrastructure design lifetime of T the failure probability ($\check{P}_T$) is calculated as:

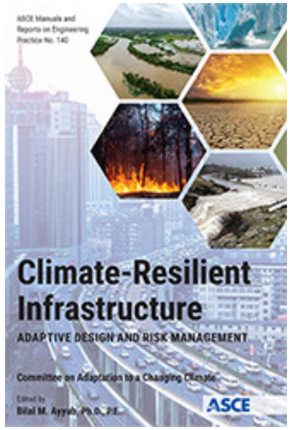
Univariate

$$p_F = 1 - (1 - p)^T$$

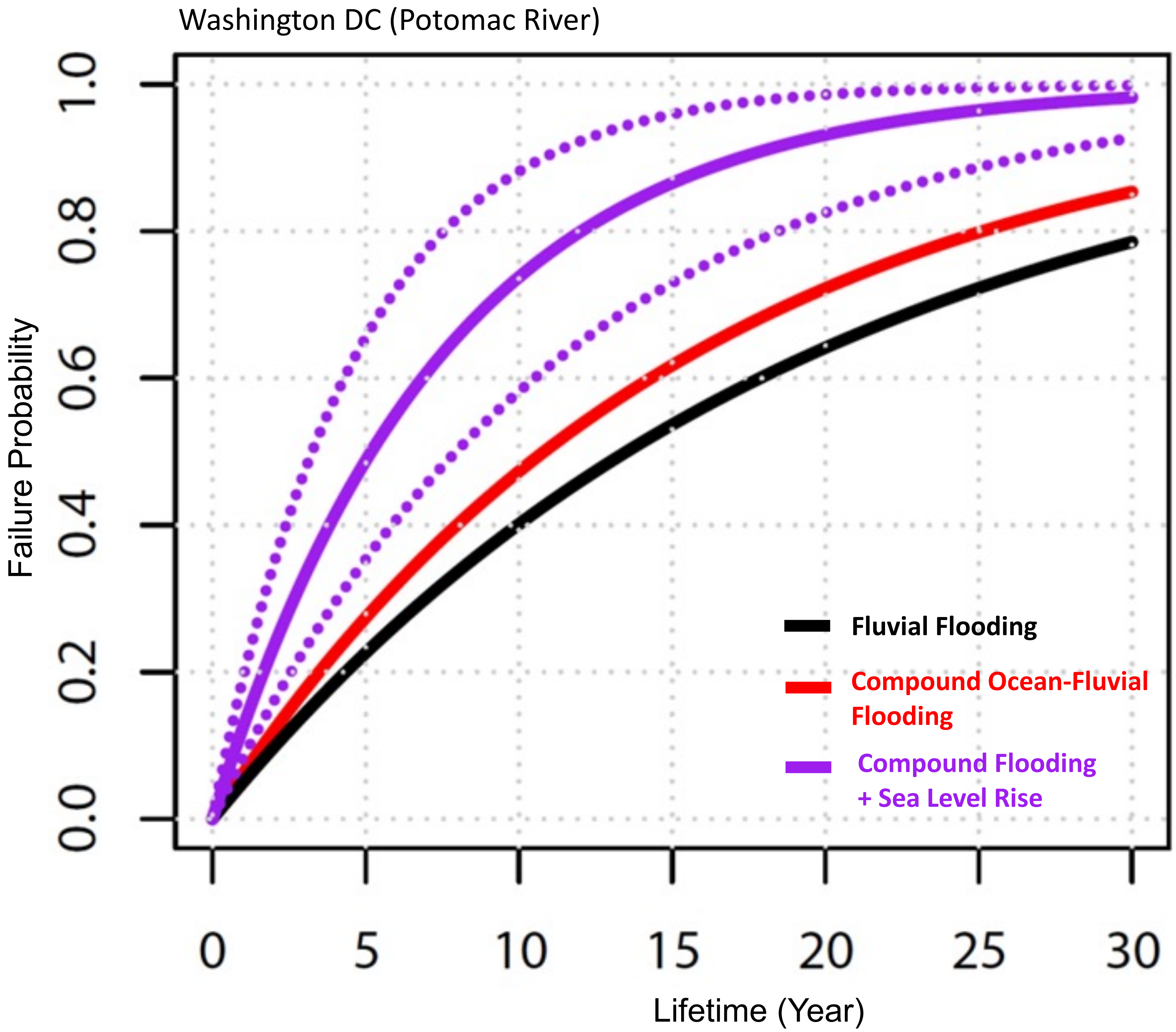
Multivariate

(Moftakhari, et al., 2017, *PNAS*)

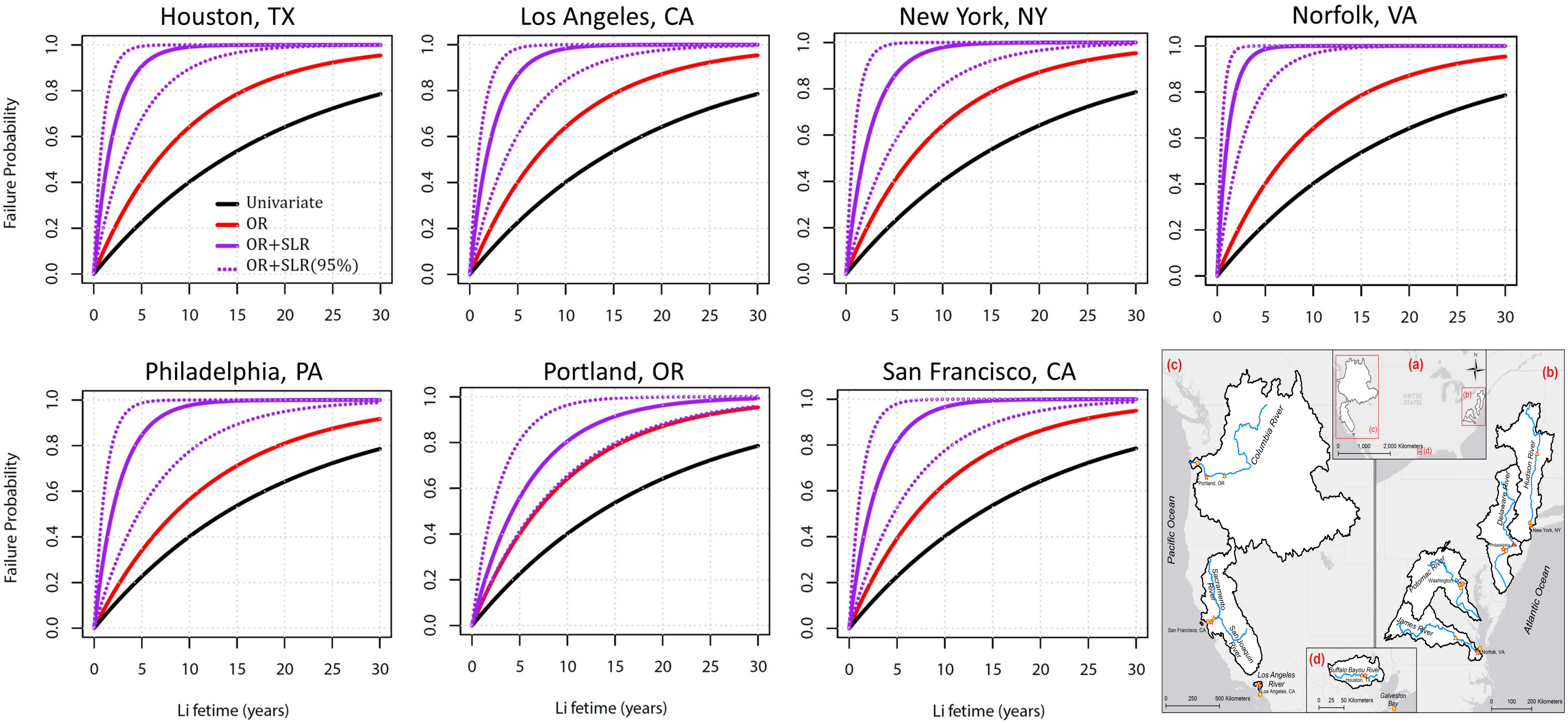
$$p_F = 1 - P\left(X_1 \in S_1^C, \dots, X_T \in S_T^C\right) = 1 - \left(C_X\left(F_1(\tilde{x}_1), F_2(\tilde{x}_2)\right)\right)^T$$



ASCE Manual of Practice 140



Compound Coastal Flooding



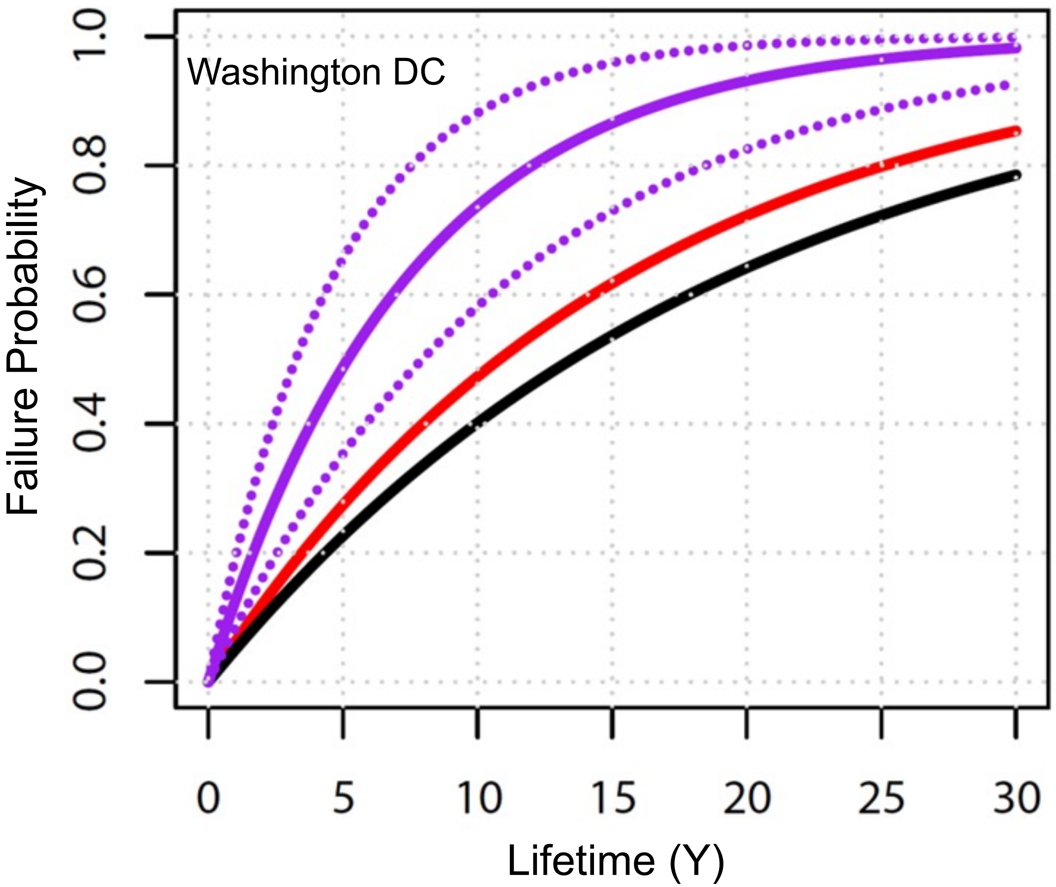
Moftakhari, et al., 2017, *PNAS*

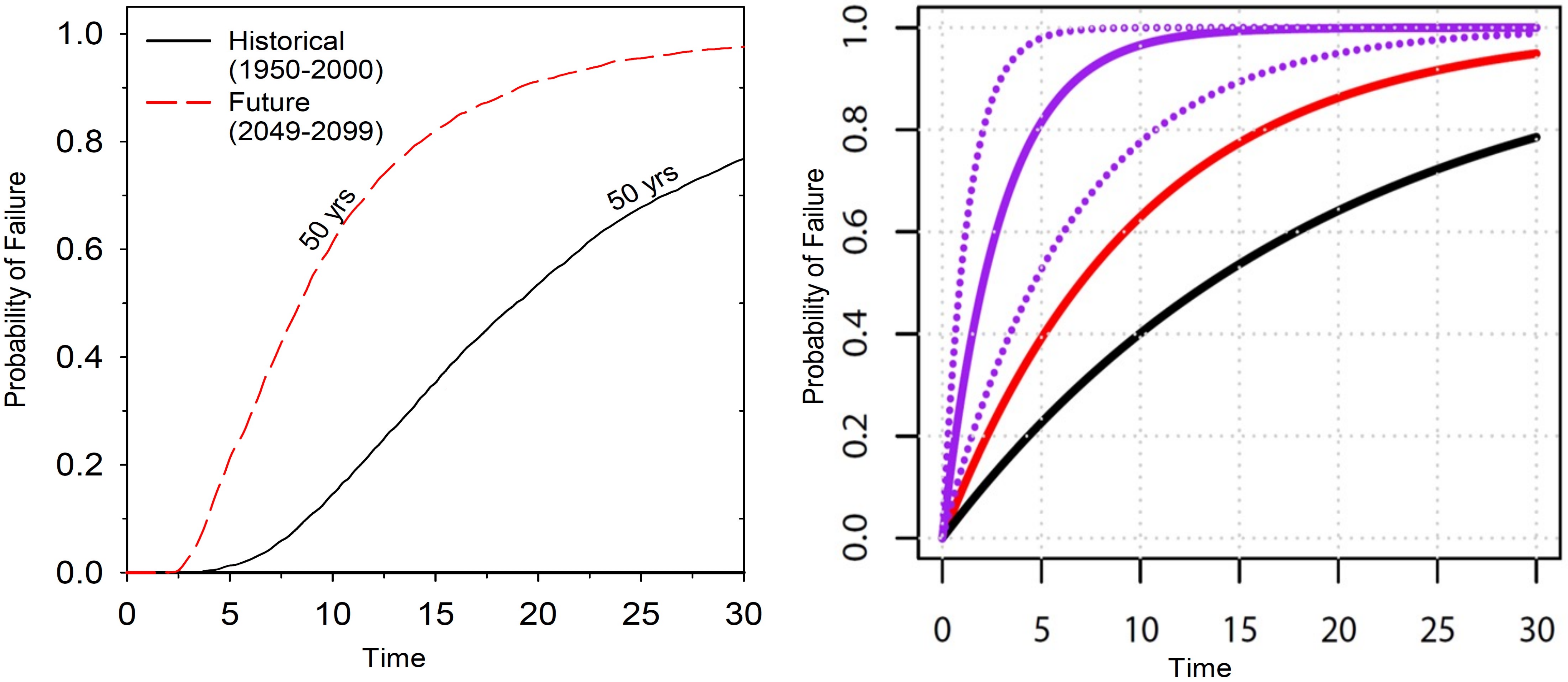
Alaska, USA

California, USA


California


Alaska

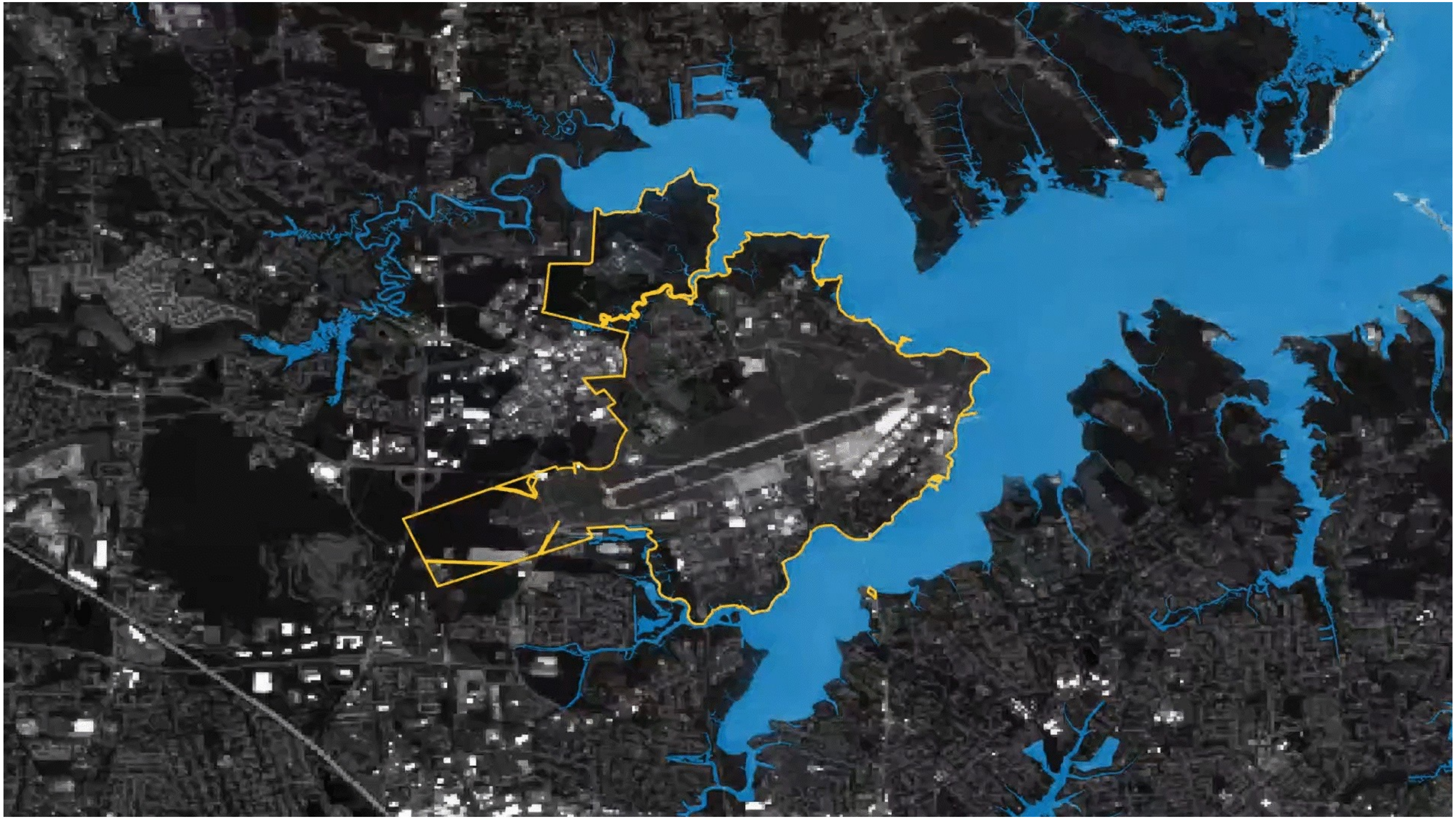

Washington DC
Failure Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30
Lifetime (Y)



Linking **Statistical Failure** Probability to **Physical Failure**
(Bridging the Gap between Climate Science and Engineering)

Vahedifard, et al., 2019, *JGGE*

In the United States, there are at least **400 federal facilities** identified as being at risk from rising sea levels and compound coastal floods. The list includes thirteen executive agencies, including **Departments of Defense military bases**.



Source: Bloomberg Law

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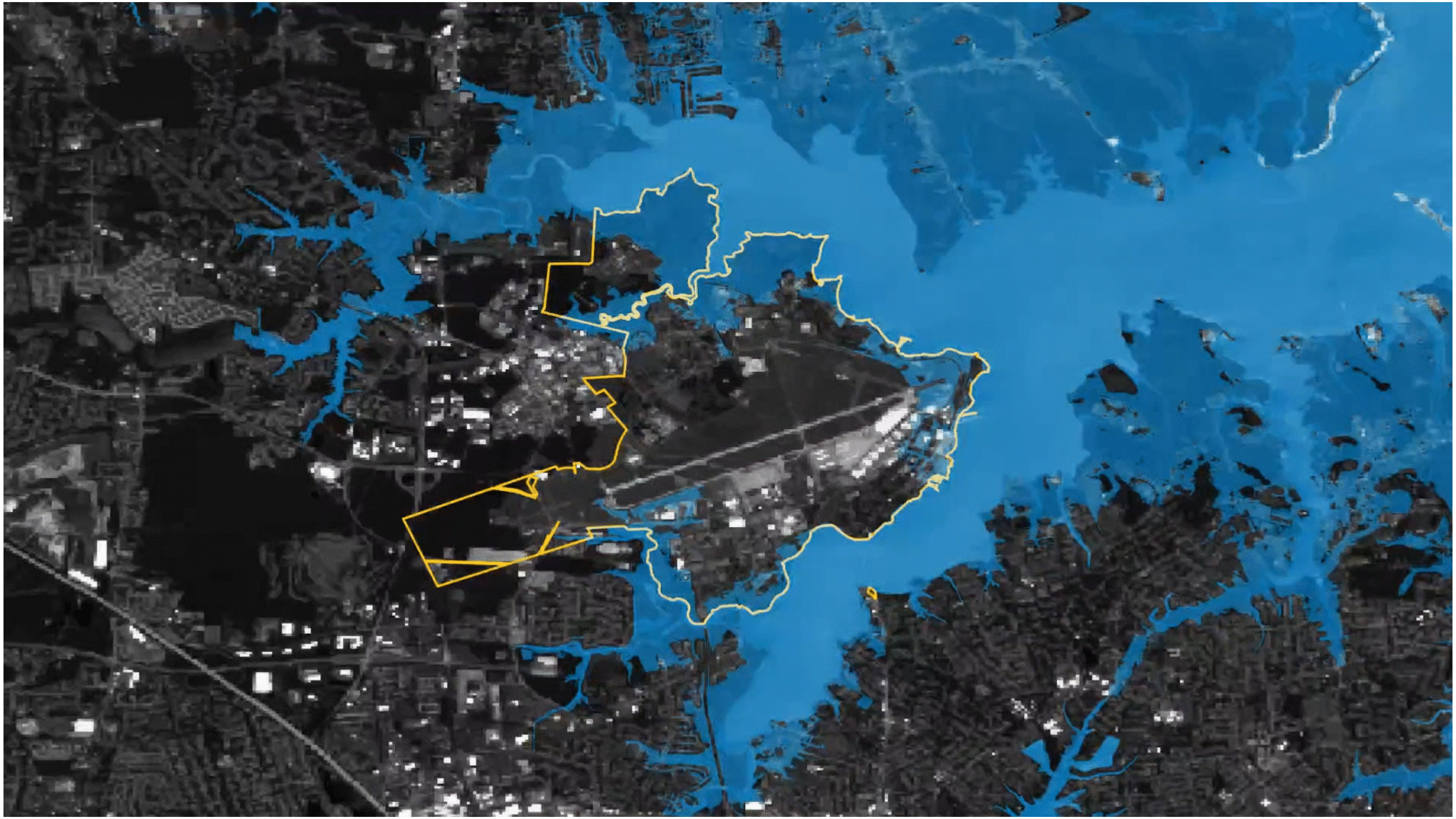
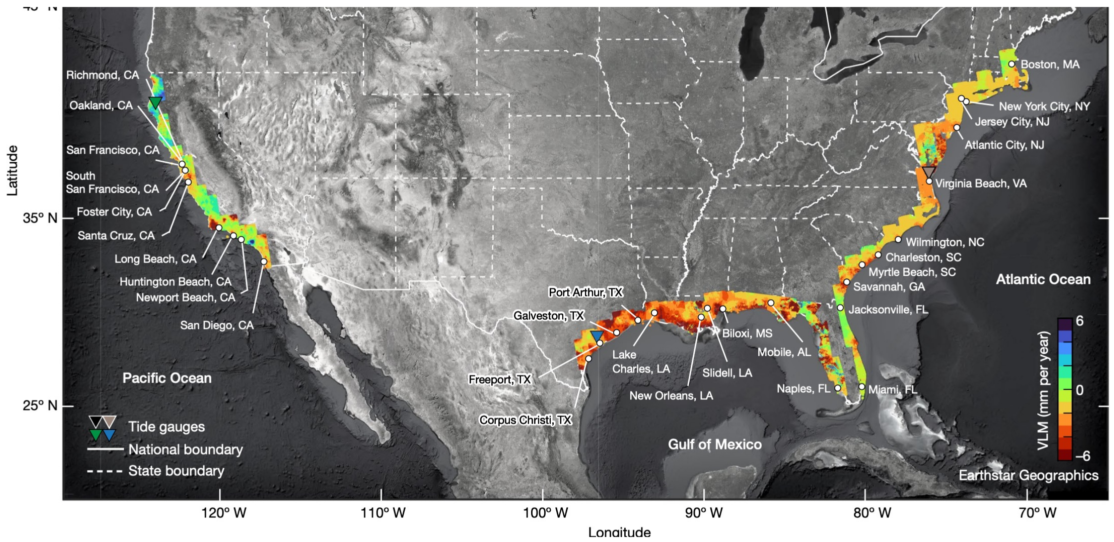


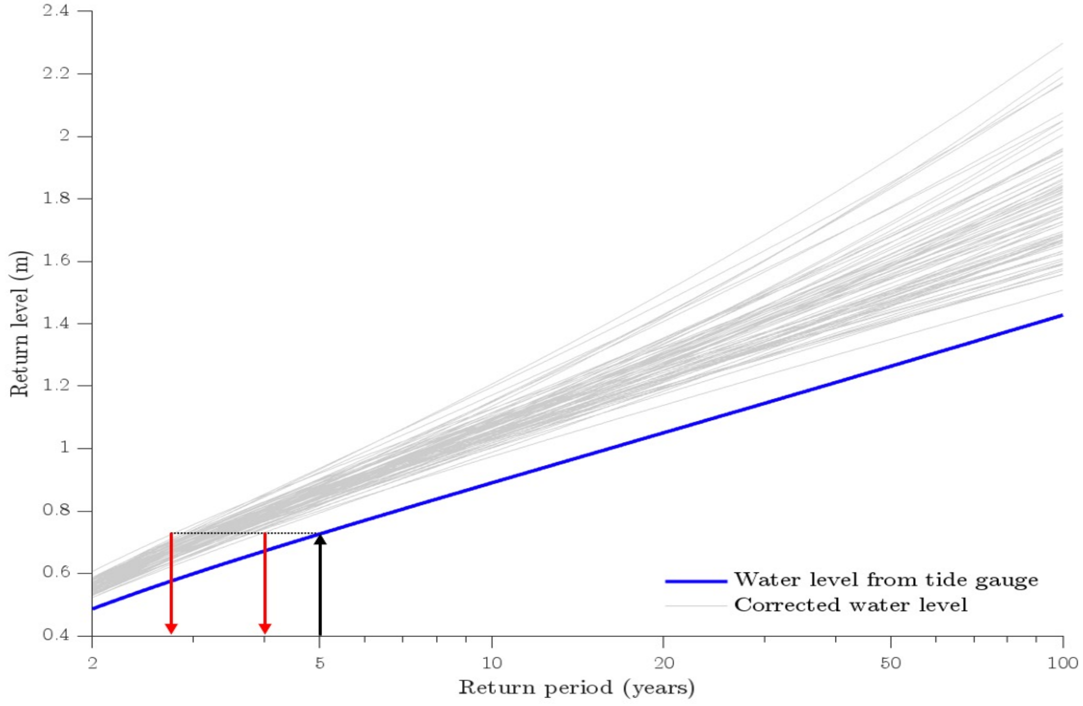
Source: Bloomberg Law

In the United States, there are at least 400 federal facilities identified as being at risk from rising sea levels and compound coastal floods. The list includes thirteen executive agencies, including Departments of Defense military bases.

Source: Bloomberg Law

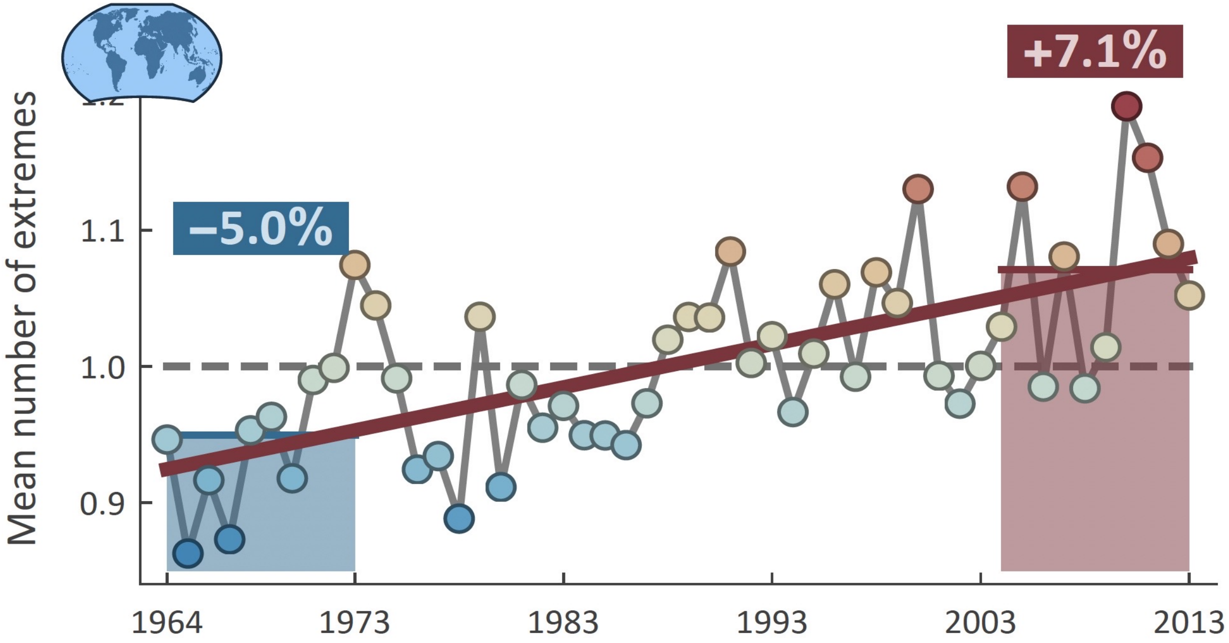
Vertical Land Motion (VLM) data

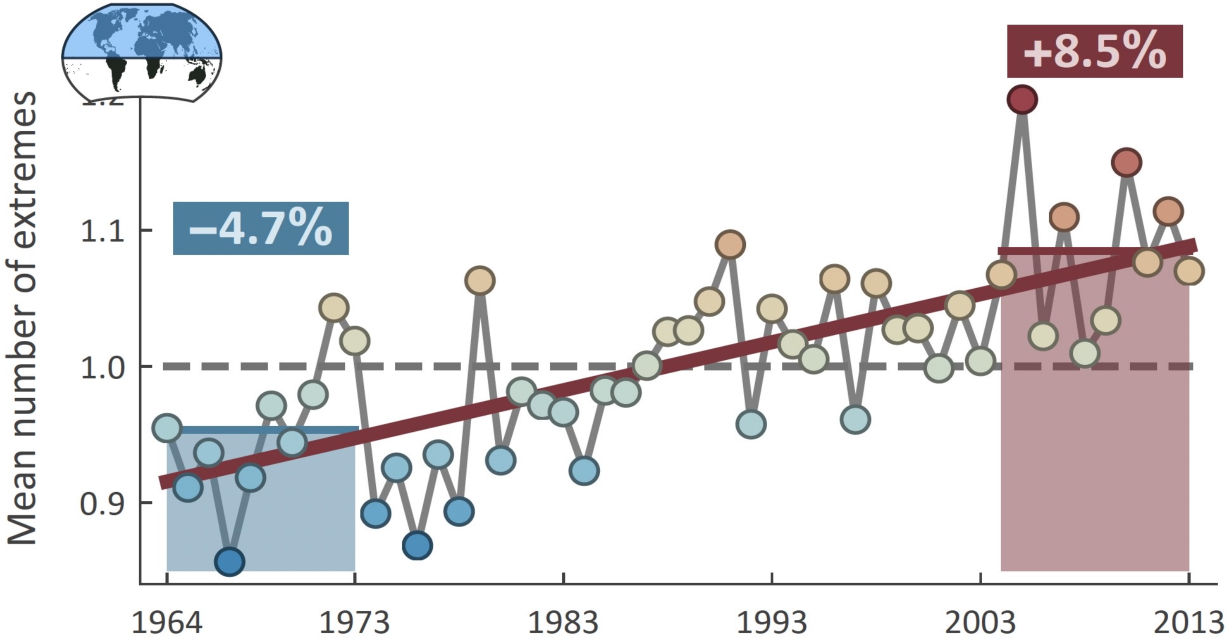


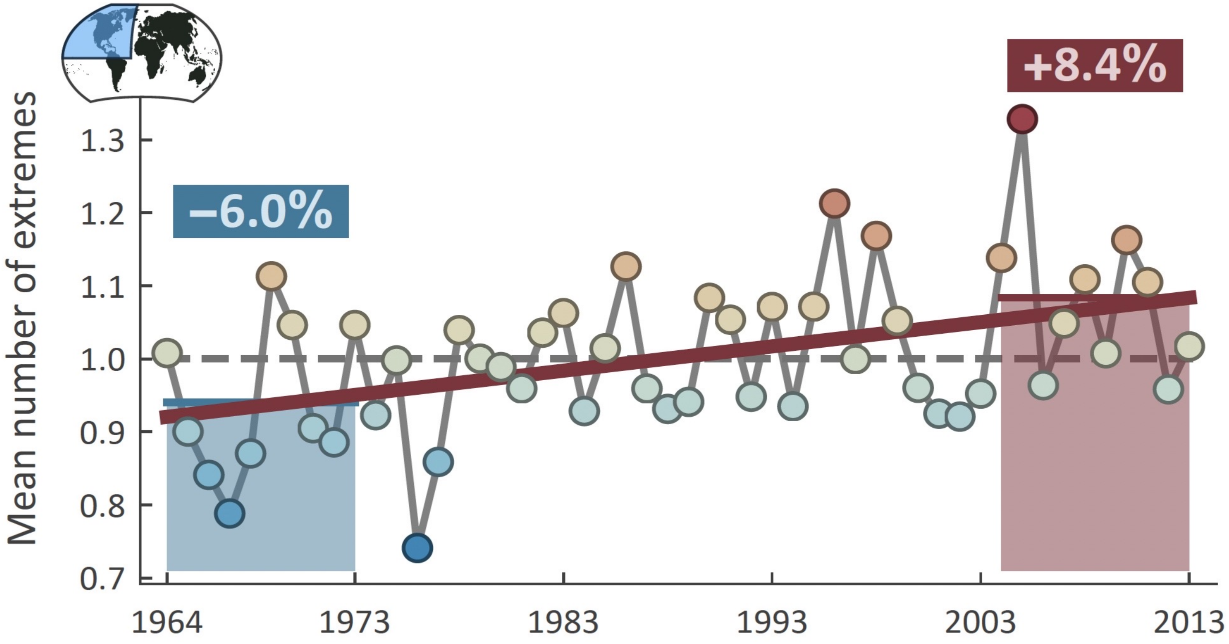


Shirzaei et al. (2021) *Nature Reviews*

Risk Assessment and Non-stationarity



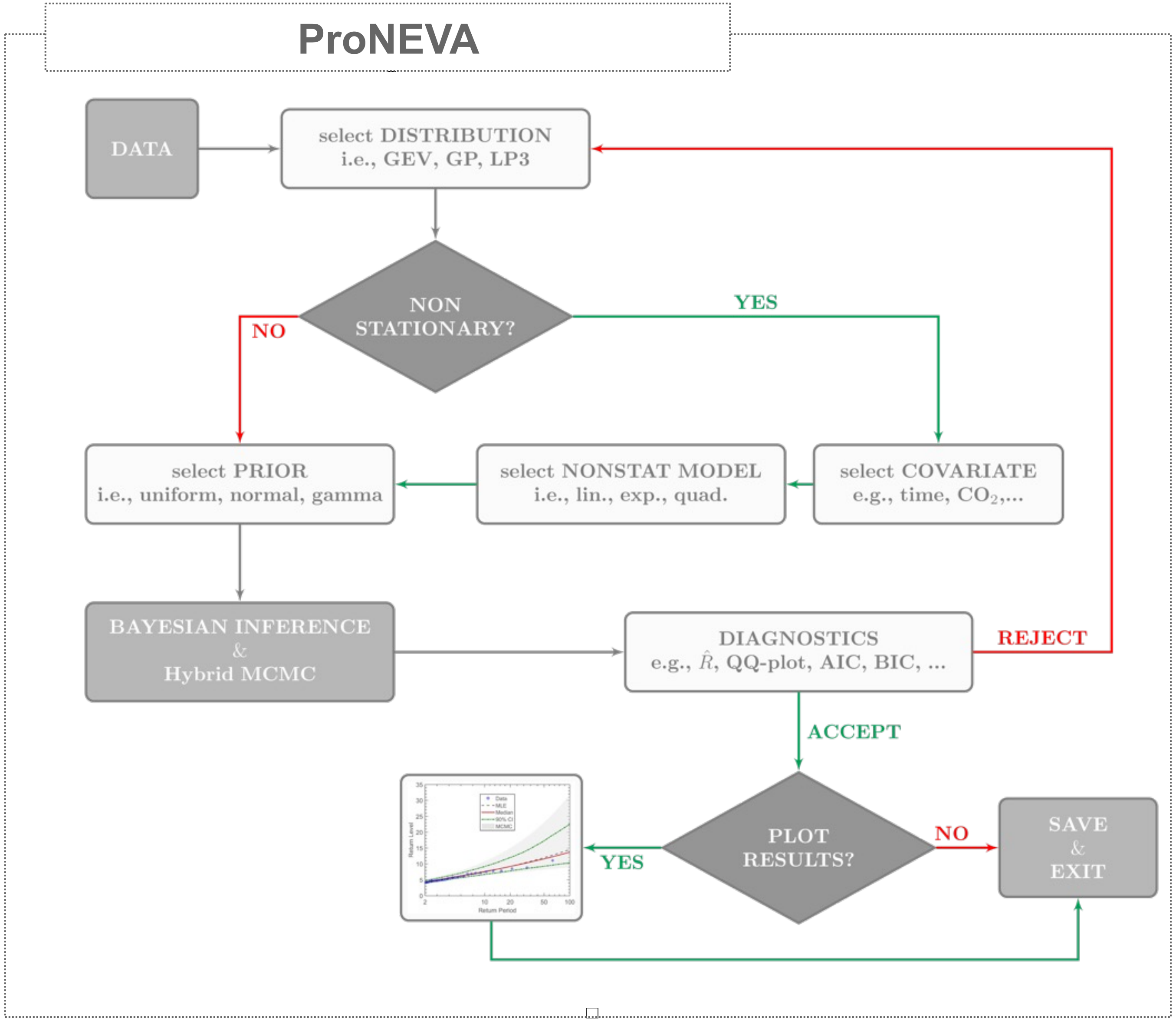




Considering the *N* largest precipitation extremes in an *N*-year record, under the assumption of stationarity, we expect no significant trend (i.e., on average one extreme per year). Analysis of 8,730 records shows evidence of change in the frequency of extreme precipitation around the world.

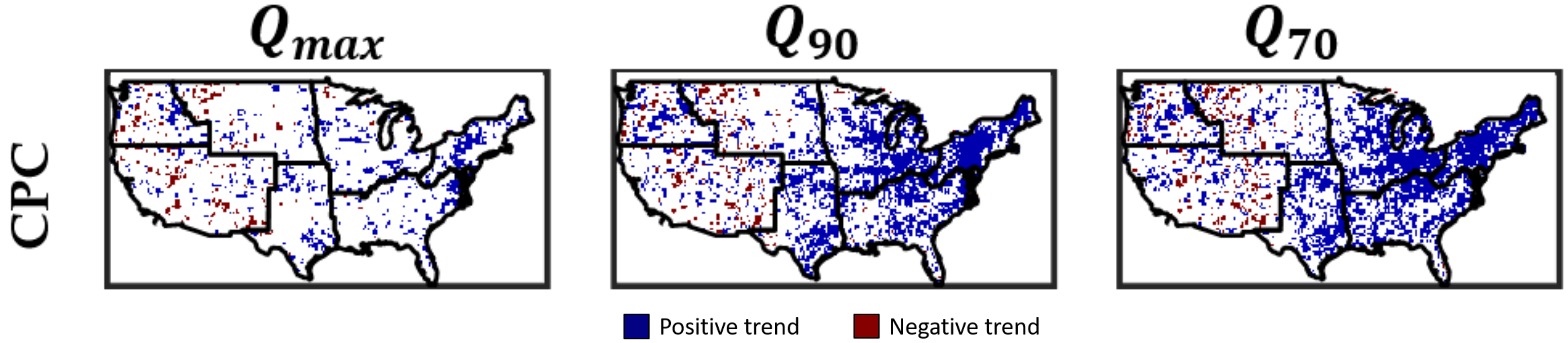
AghaKouchak et al., 2020, *Annu Rev Earth Planet Sci*

Process-informed **N**onstationaty **E**xtreme **V**alue **A**nalysis (**ProNEVA**)

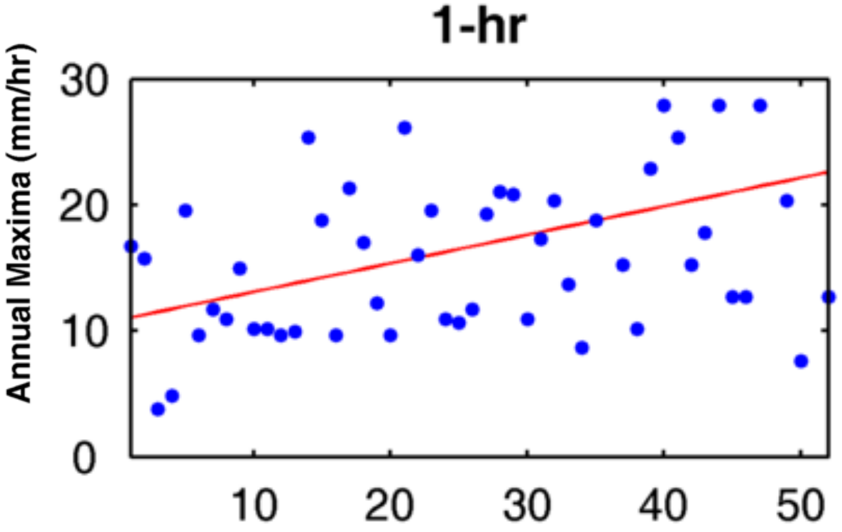


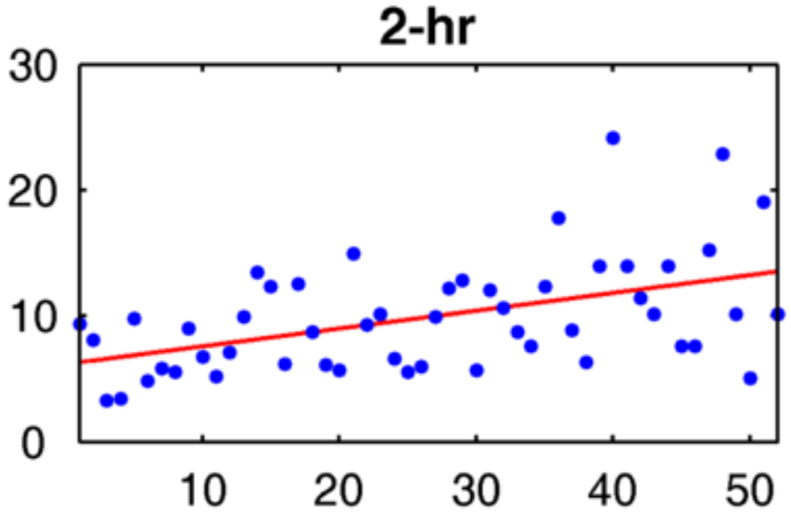
Ragno et al., 2019, *Advances in Water Resources*

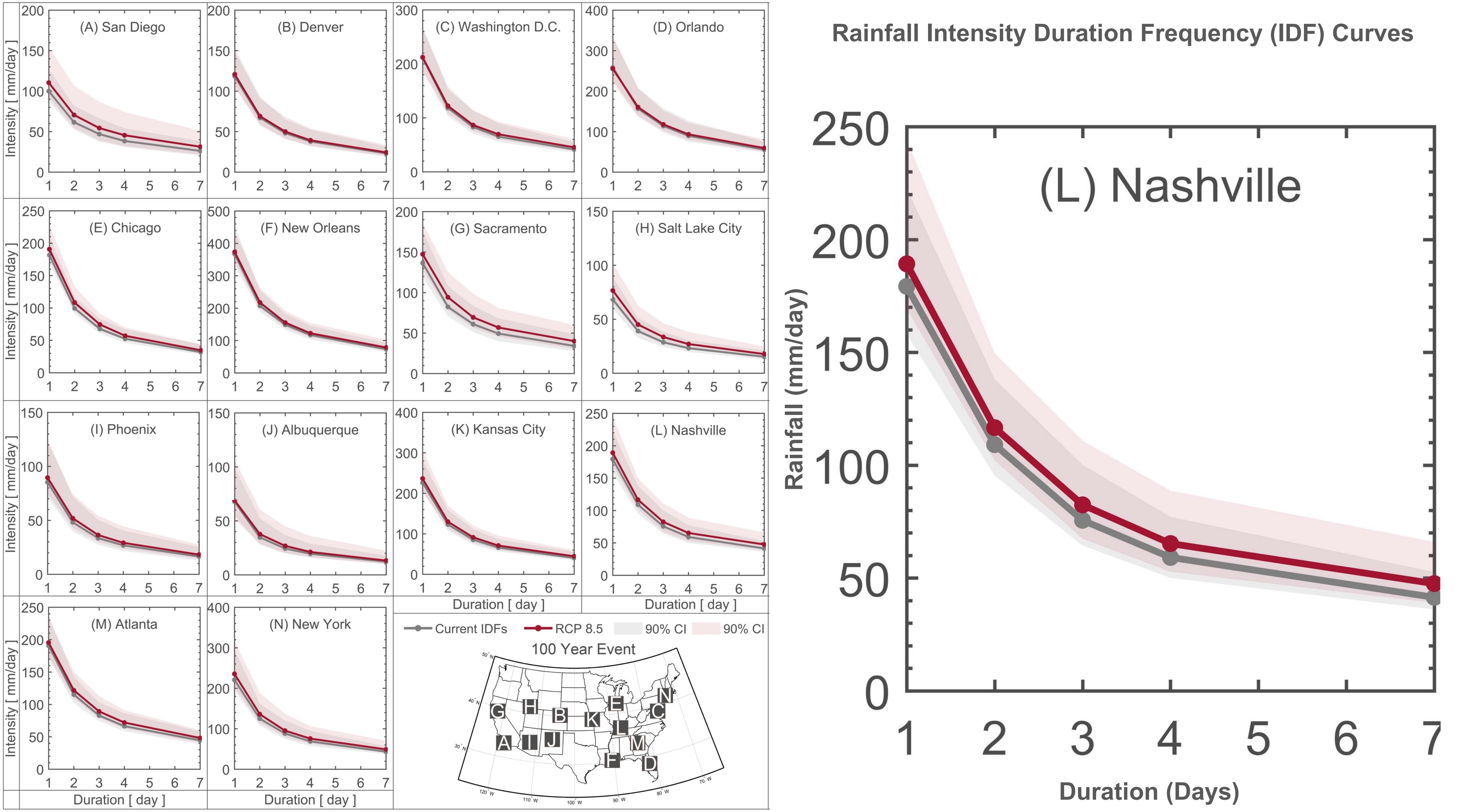
http://amir.eng.uci.edu/downloads/ProNEVA.zip



Trends in the magnitude of different annual precipitation quantiles (Q_{70}, Q_{90}, Q_{max}) during 1983–2017. Blue (red) color shows regions with statistically significant increasing (decreasing) trends at the 5% level. Data: Gauge-based Climate Prediction Center (CPC) precipitation data (Mallakpour et al., 2021).

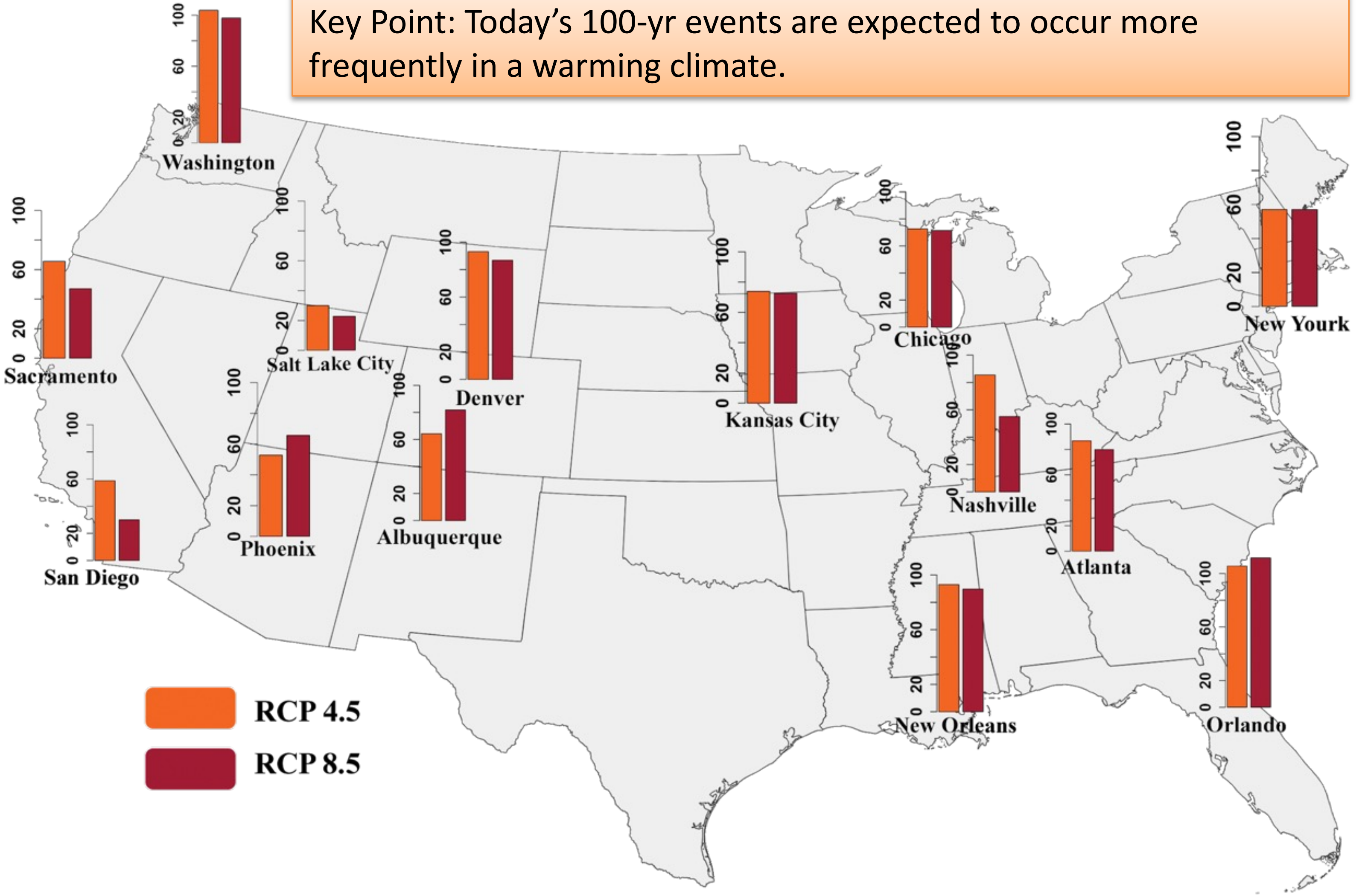




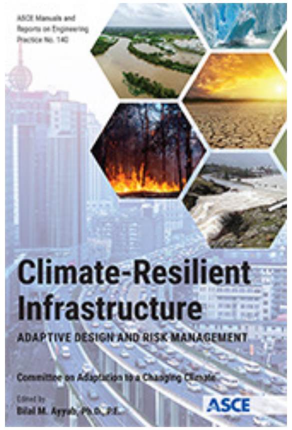


(A) San Diego
(B) Denver
(C) Washington D.C.
(D) Orlando
(E) Chicago
(F) New Orleans
(G) Sacramento
(H) Salt Lake City
(I) Phoenix
(J) Albuquerque
(K) Kansas City
(L) Nashville
(M) Atlanta
(N) New York
Intensity [mm/day]
Duration [day]
Current IDFs
RCP 8.5
90% CI
90% CI
100 Year Event
Rainfall Intensity Duration Frequency (IDF) Curves
(L) Nashville
Rainfall (mm/day)
Duration (Days)

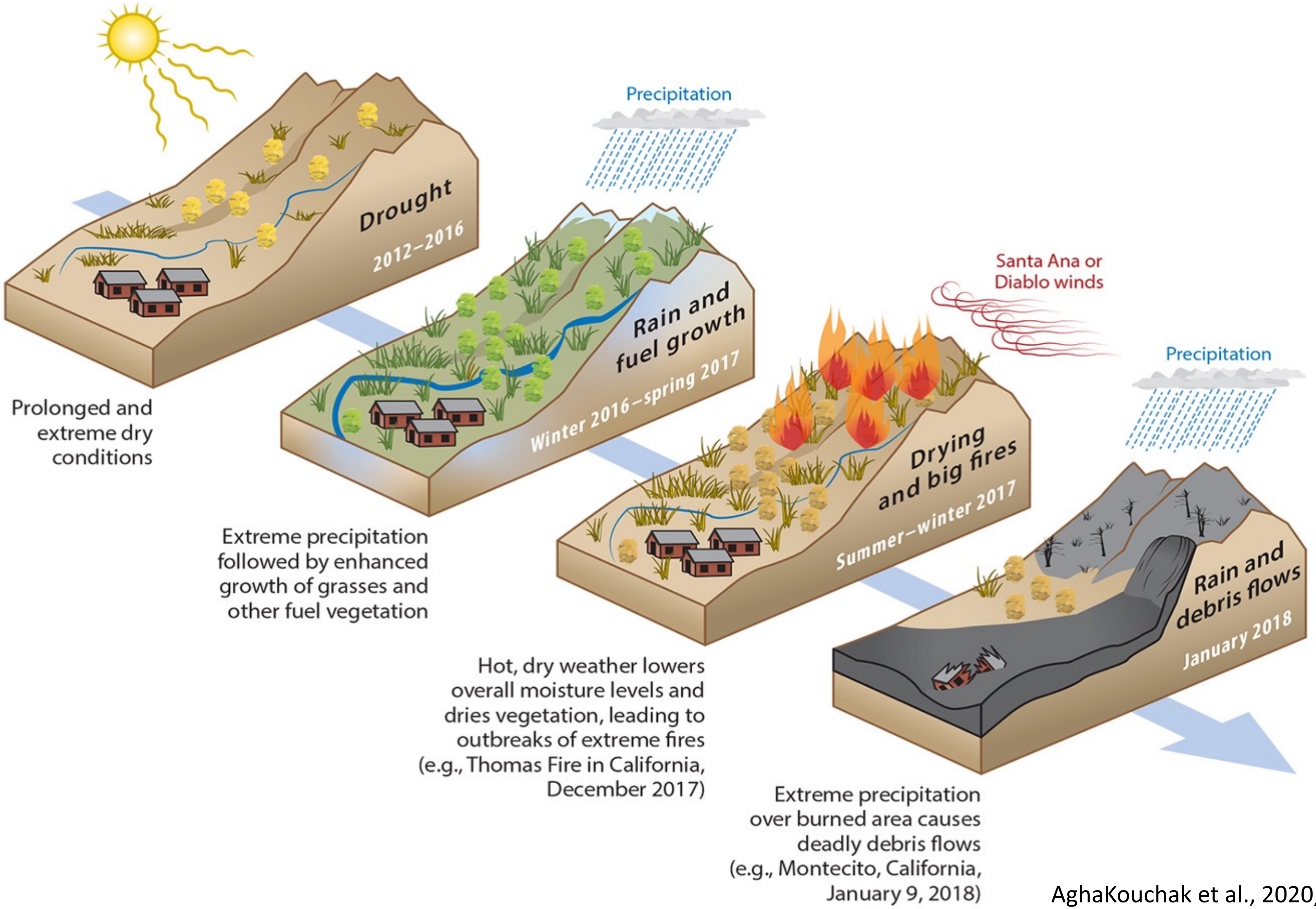
Key Point: Today's 100-yr events are expected to occur more frequently in a warming climate.



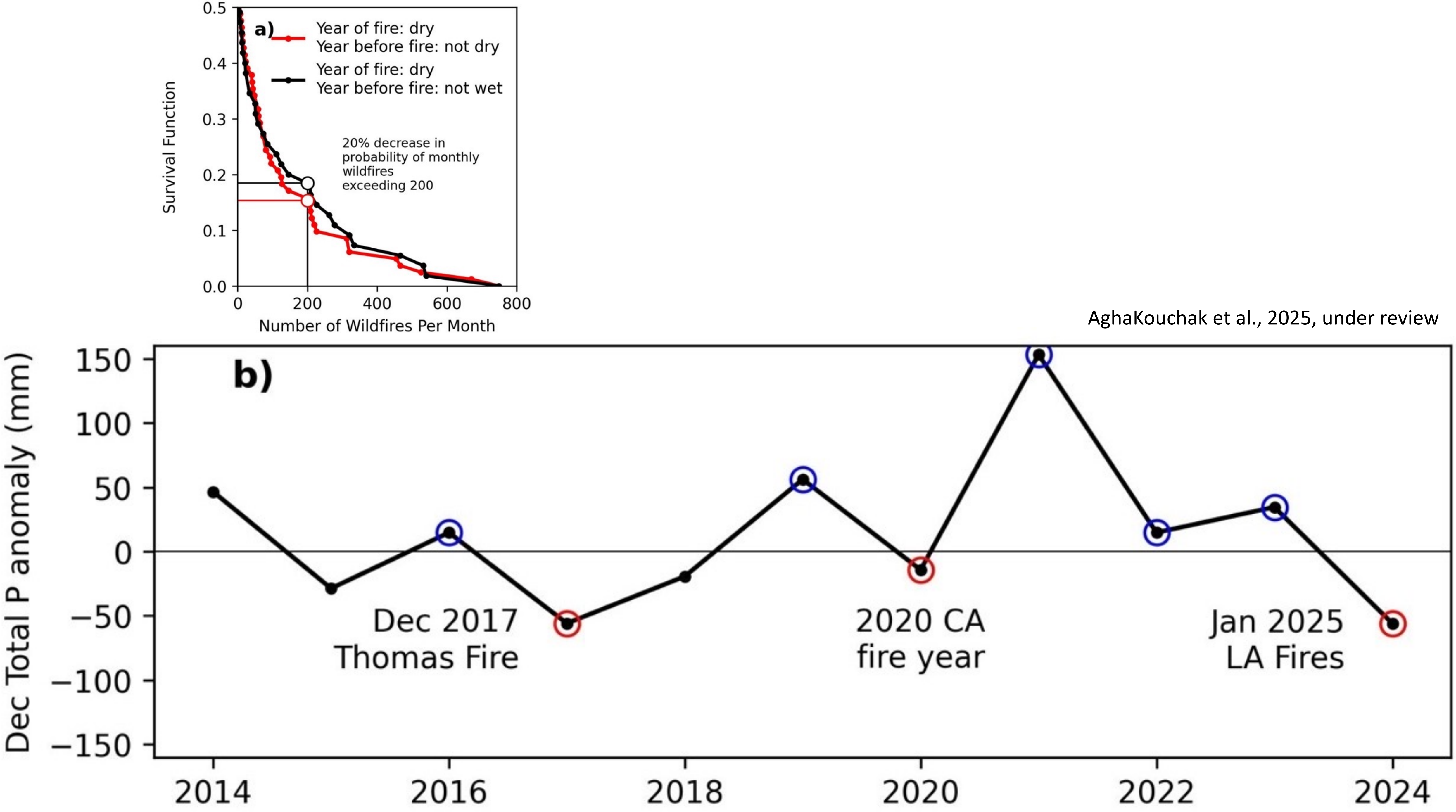
Return periods of extreme precipitation under future climate of events currently associated with return periods of 100 years in urban locations across the United States. For instance, in San Diego, a flood currently associated with a 100 year return period is projected to have a return period of 59 and 30 years under RCP 4.5 and 8.5, respectively (data from Ragno et al., 2018).



ASCE Manual of Practice 140: Methodology recommended to quantify changes in statistics of extreme rainfall for infrastructure design and risk assessment.



AghaKouchak et al., 2020, *Annu Rev Earth Planet Sci*



AghaKouchak et al., 2025, under review

Questions?

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