UCF COASTAL
NATIONAL CENTER FOR INTEGRATED COASTAL RESEARCH

COMPOUND FLOODING: EXAMPLES, METHODS, AND CHALLENGES

Thomas Wahl

Civil, Environmental and Construction Engineering & National Center for Integrated Coastal Research

University of Central Florida

Definition(s) of compound events

IPCC, 2012:

(1) two or more extreme events occurring simultaneously or successively; (2) combinations of extreme events with underlying conditions that amplify the impact of the events; or (3) combinations of events that are not themselves extremes but lead to an extreme event or impact when combined. The contributing events can be of similar (clustered multiple events) or different type(s).

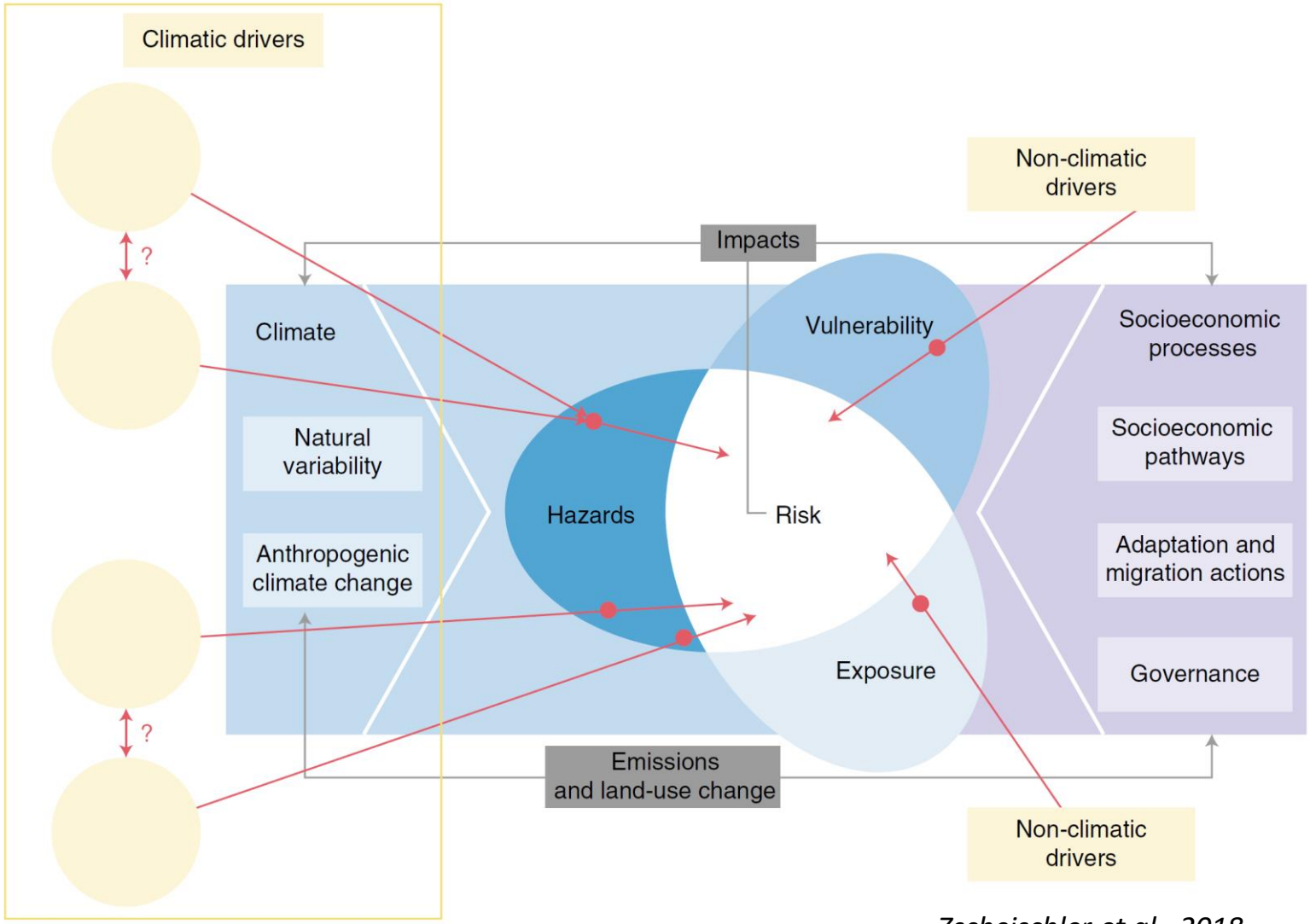
Leonard et al., 2014:

A compound event is an extreme impact that depends on multiple statistically dependent variables or events.

Zscheischler et al., 2018:

The combination of multiple drivers and/or hazards that contributes to societal or environmental impacts.

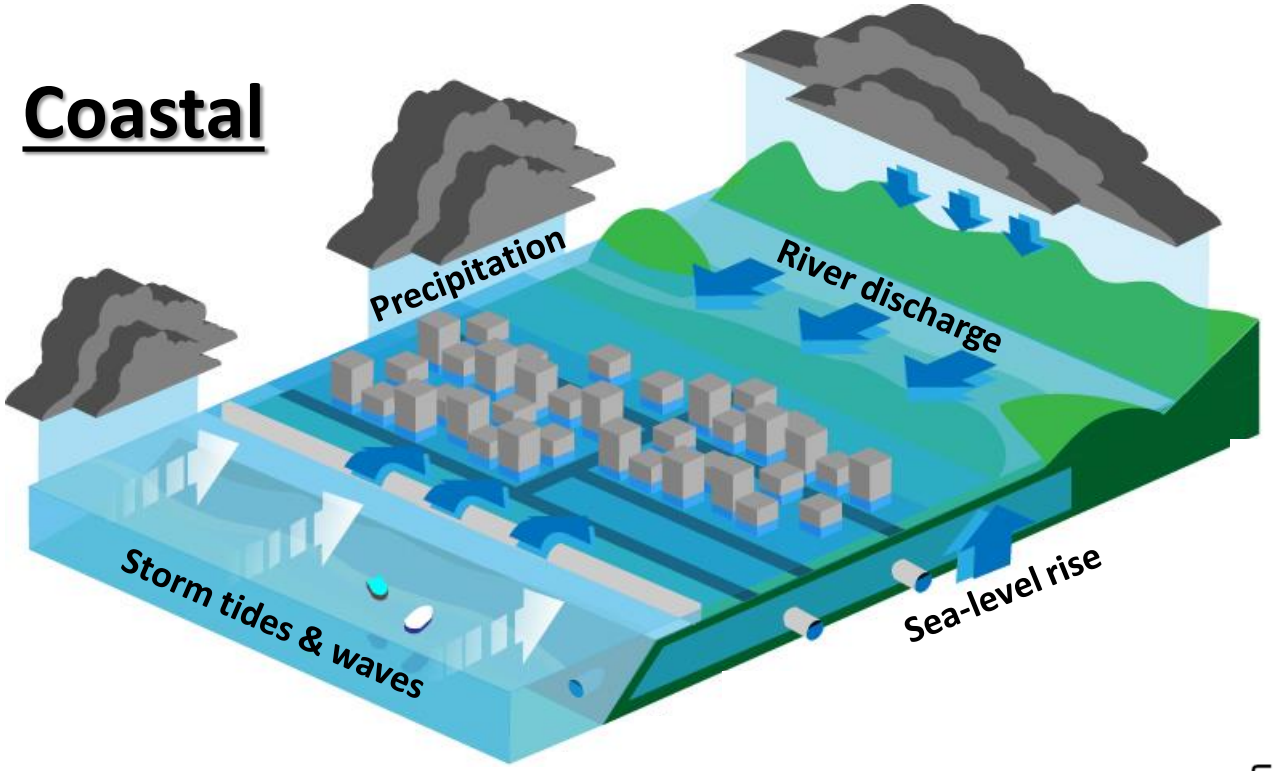
Definition(s) of compound events



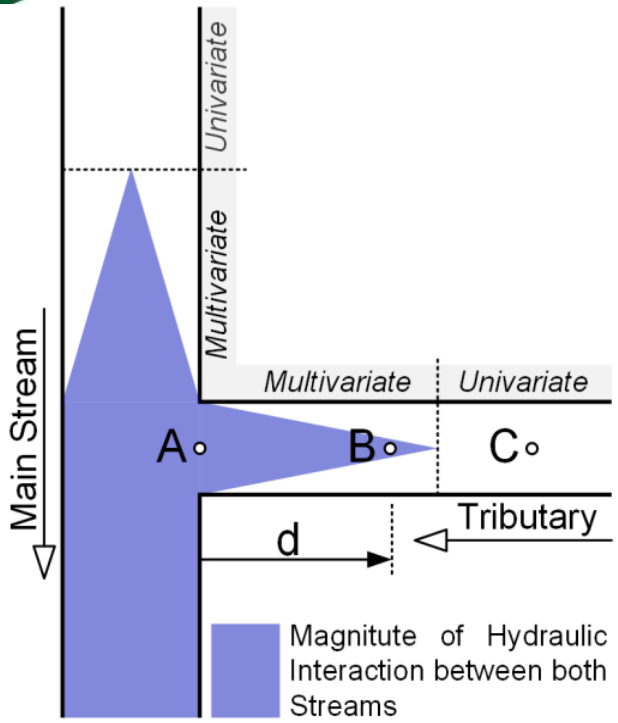
Zscheischler et al., 2018

Types of compound flooding

Coastal



River confluences



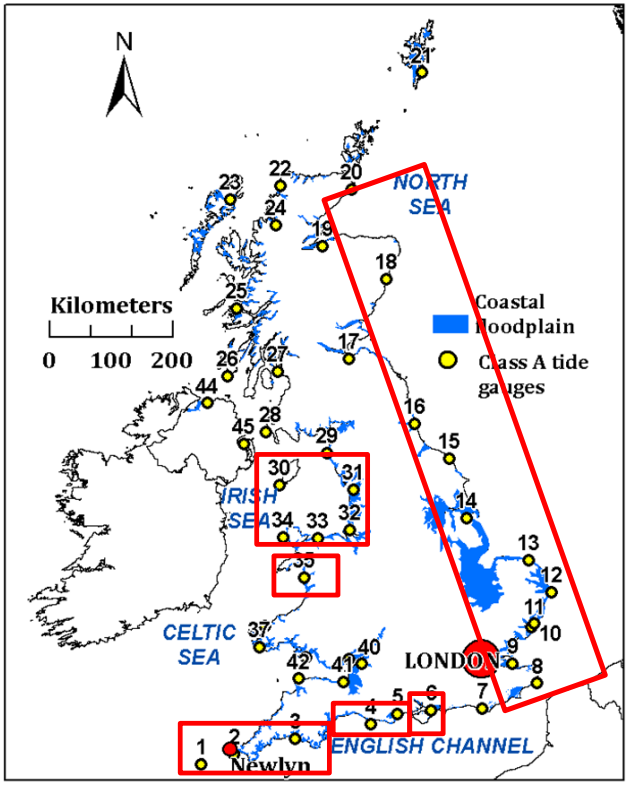
Bender et al., 2016

Examples

Compound flooding in the upper Danube basin (city of Passau) from high discharges into the confluence of the rivers Danube, Inn and Ilz.

Compound flooding in the city of Jacksonville from the combination of storm surge and high discharge of the St. John's river during hurricane Irma.

Compound flooding in Galveston from extreme precipitation and moderate but long-lasting storm surge during hurricane Harvey.



27-28 Oct, 'St Jude' Storm
99 mph winds
Yarmouth: floods neap tide

5-6 Dec, Xaver Storm
East coast surge
Repeat of 1953?

1-3 Jan,
Wales, Dorset
badly hit

1- 5 & 14 Feb,
Destruction Dawlish
railway

3 Mar,
flooding in
Jersey

October | November | December | January | February | March

2013 2014

Photo source: BBC

Methods

Dependence of marginal parameters

statistical independence (e.g. χ^2-Test)

multiplication of marginal exceedance probabilties

statistical dependence (e.g. $r \neq 0$)

multivariate models

Marginal distributions

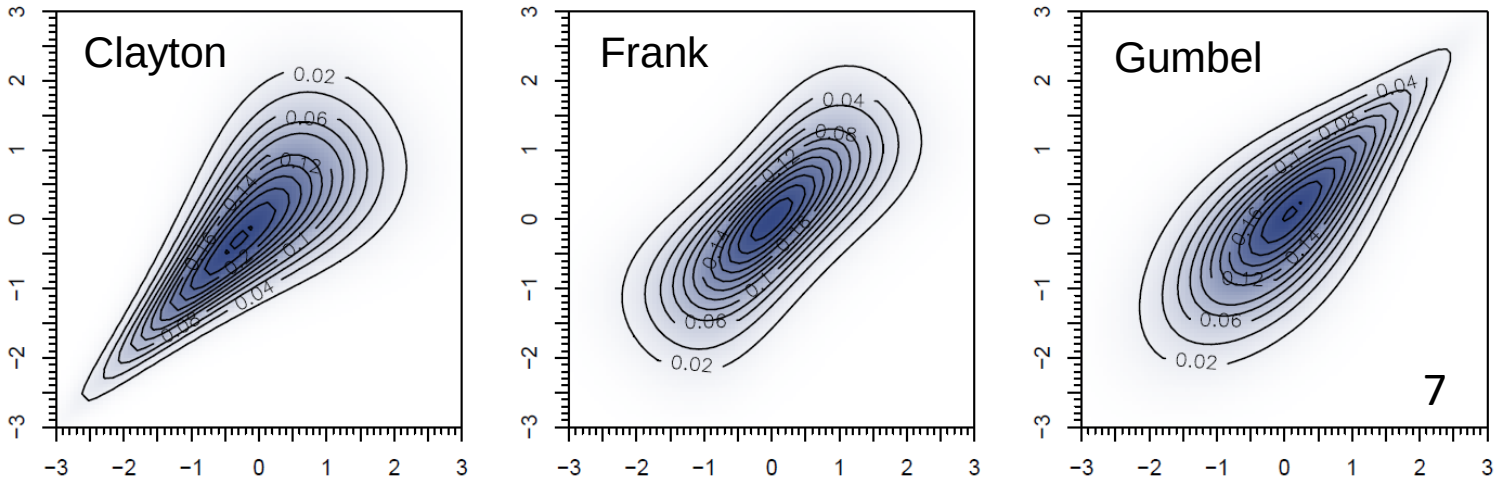
same marginal distributions

mixed marginal distributions

multivariate parametric models (e.g. bivariate Gumbel model)

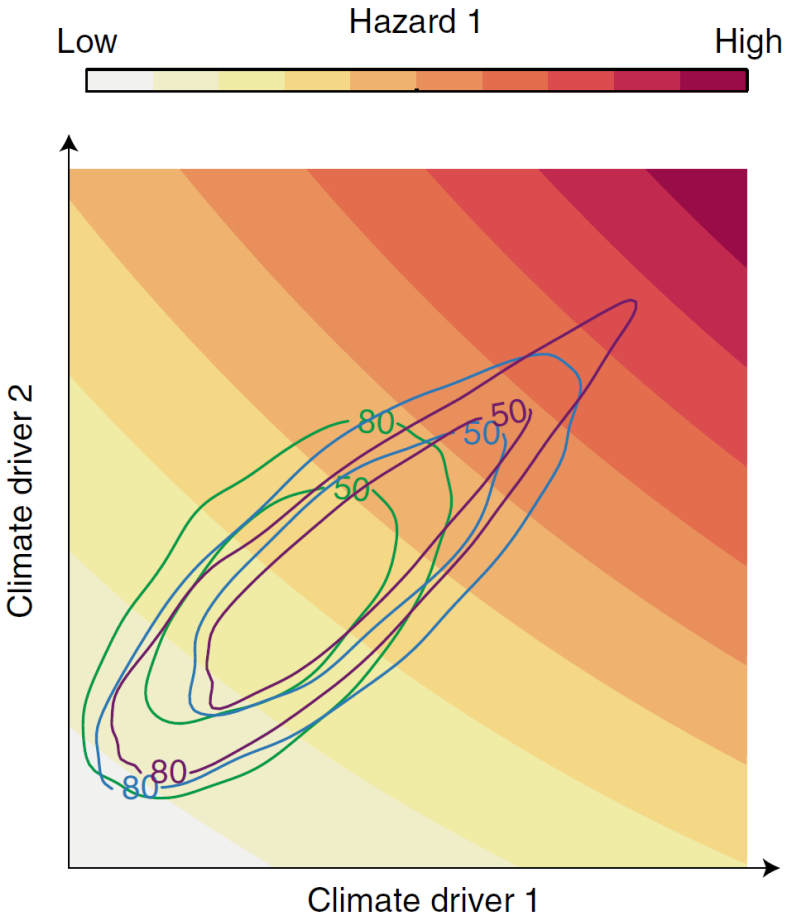
Copula models (e.g. Gumbel, Frank, Clayton)

Archimedean Copula family



Non-stationarity

Non-stationarity in the multivariate case can come from either of the relevant variables (e.g. trends, cycles etc.) or changes in their dependency.



Green: hypothetical distribution of two climatic drivers in the present climate.

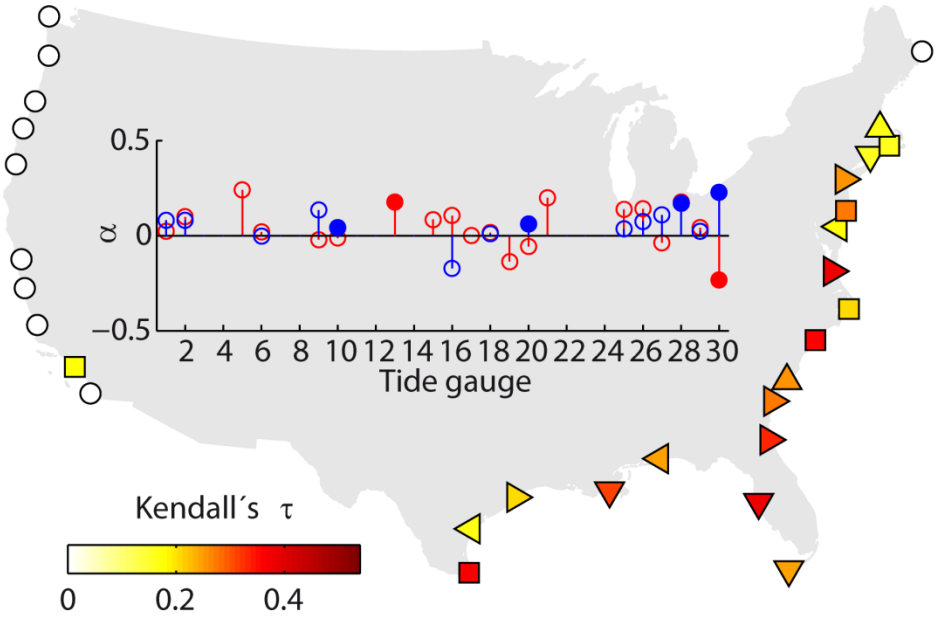
Blue: a future climate with shift in mean, variability and correlation between the drivers.

Purple: future climate with an increase in dependence in the upper tail of both drivers.

Non-stationarity

The risk of compound flooding is assessed using sea level records from 30 tide gauges (> 30 years of data) and precipitation data from stations within 25 km (averaged into indices for each tide gauge).

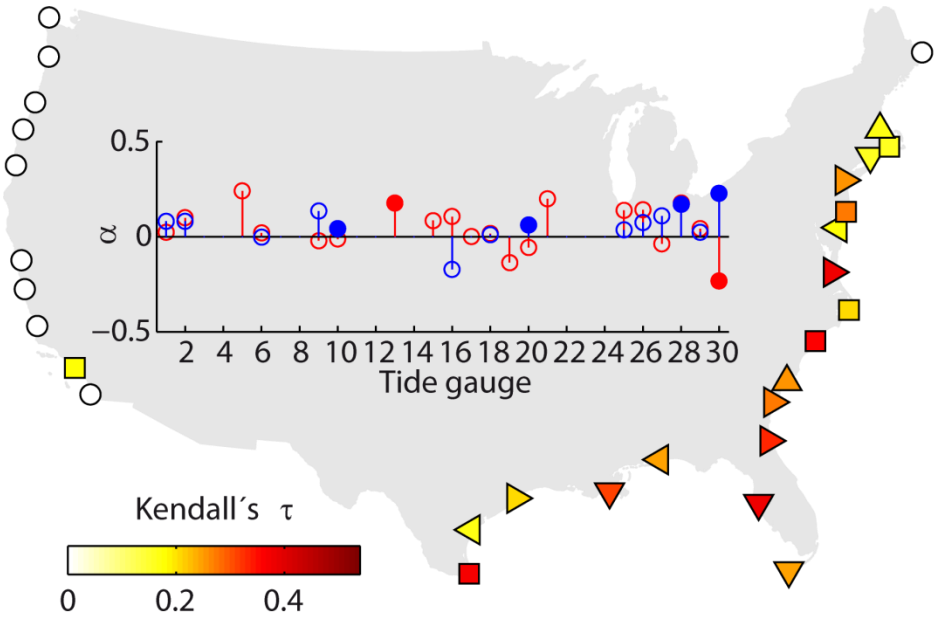
The dependency between the two proxies and the spatial and temporal variability are analyzed:

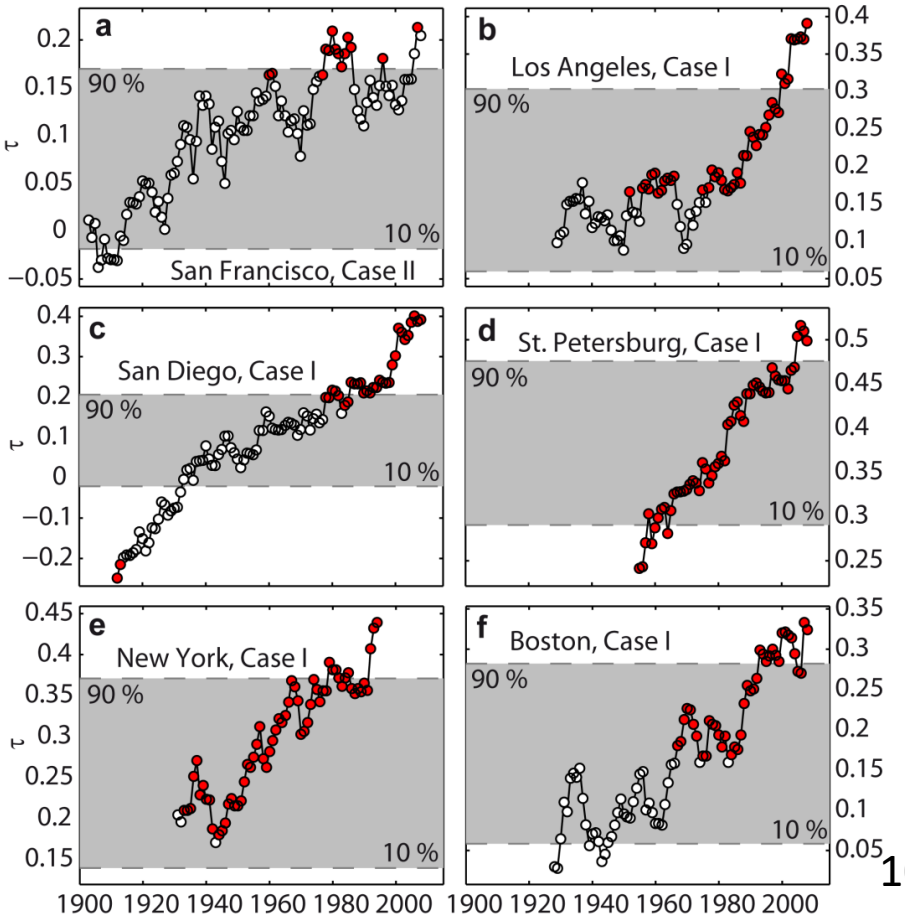


Non-stationarity

The risk of compound flooding is assessed using sea level records from 30 tide gauges (> 30 years of data) and precipitation data from stations within 25 km (averaged into indices for each tide gauge).

The dependency between the two proxies and the spatial and temporal variability are analyzed:



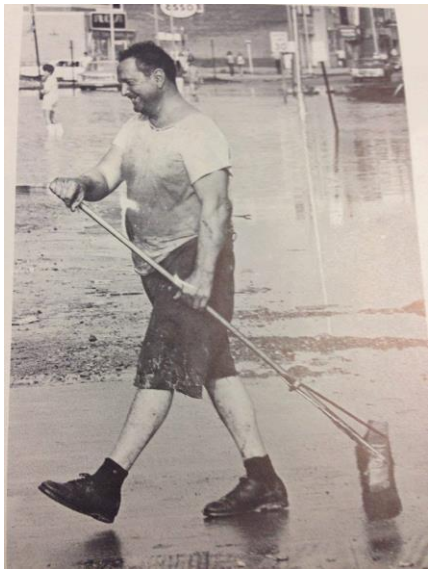


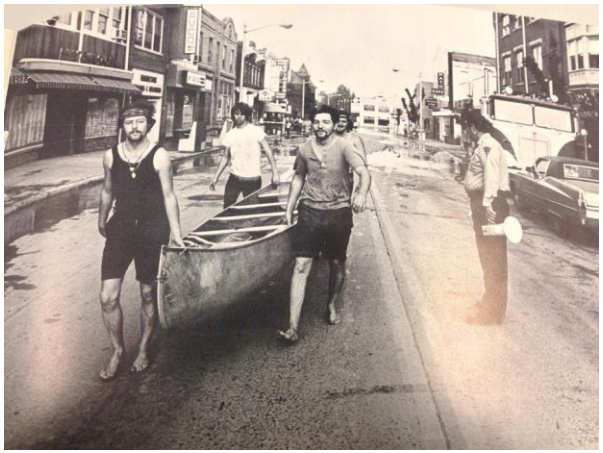
Non-stationarity

Extreme Value Analysis:

We select a random extreme event combination (comprised of 120 mm daily rainfall and 115 cm storm surge; i.e. similar to tropical storm Doria) and quantify the effect of the increased dependency on multivariate ("AND") return periods:

- Independence assumption: $RP_{mult,\ ind}$ **≈ 245 yrs**
- Using small correlation as observed in the 1940s: $RP_{mult,\ \tau 1940s}$ **≈ 105 yrs**
- Using large correlation as observed recently: $RP_{mult,\ \tau 2000s}$ **≈ 42 yrs**





The way forward

- Identify additional key variable and event combinations needing scrutiny. Use bottom-up approaches and perform system stress tests to identify vulnerabilities.
- Use appropriate statistical methods to simulate dependence in time (i.e., temporal clustering), space (i.e., spatial footprints) and across multiple variables.
- Identify data and model requirements for documenting, understanding, simulating and attributing compound events.
- Incorporating compound events into impact assessments and disaster risk mitigation works.

Requires close collaboration and communication between scientists from various fields (natural sciences, engineering, social sciences) as well as stakeholders and policy makers.


Thank you for your attention!