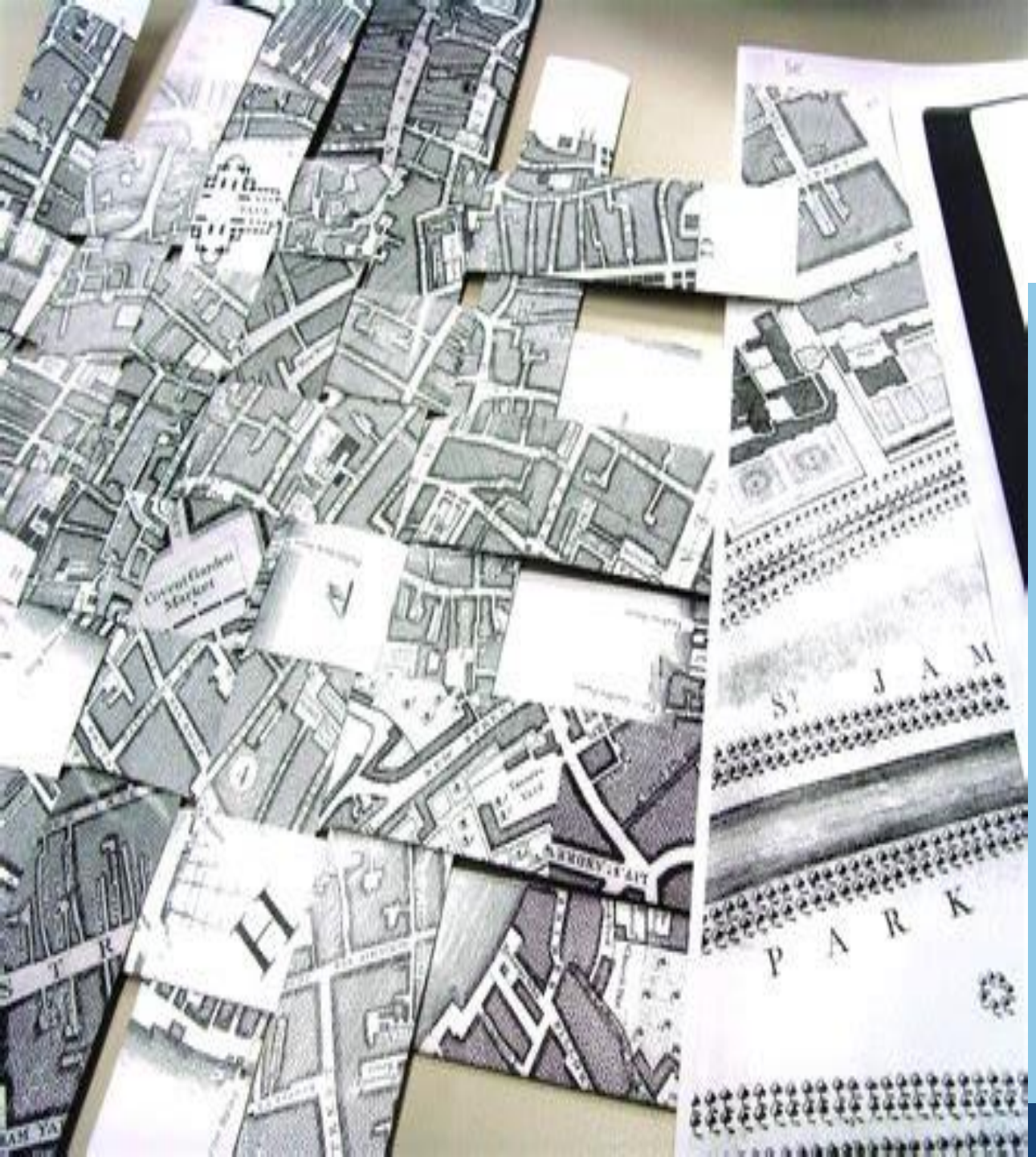
Lecture 1



cost
EUROPEAN COOPERATION
IN SCIENCE & TECHNOLOGY

Compound weather and climate events:

What are they? Why do we care?

Bart van den Hurk (Deltares)

with contributions from

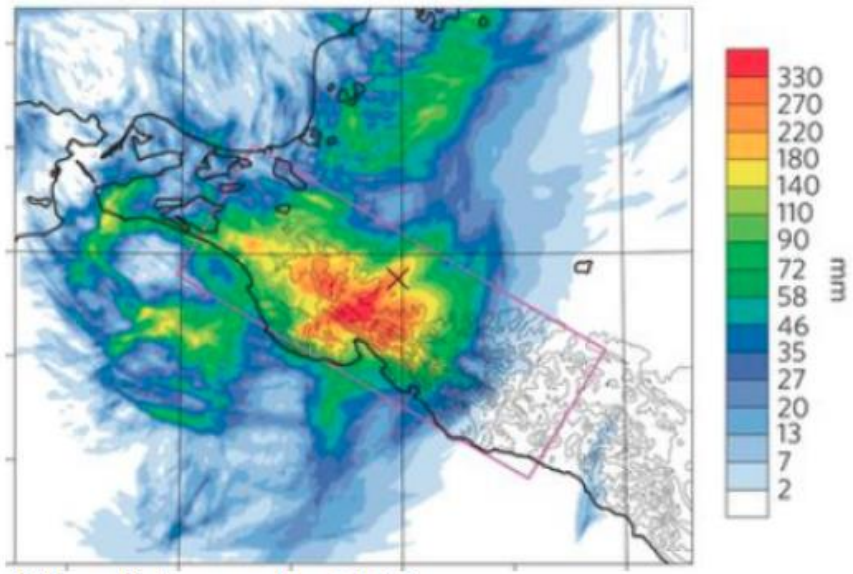
Jakob Zscheischler,

Emanuele Bevacqua and

Mercè Casas i Prat

A "typical univariate" extreme event

In 2012, a flash flooding in Krymsk (Russia) killed more than 170 people due to an unprecedented amount of rain.

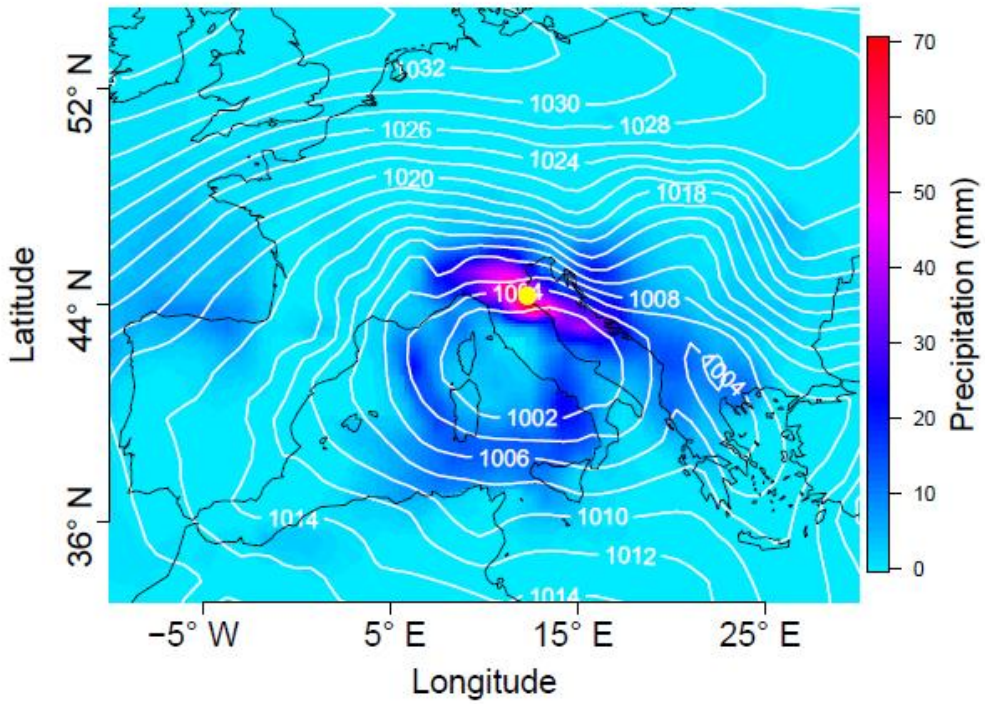


Meredith et al., 2015

But not all flooding are "univariate", many are caused by a combination of hazards/drivers.

slide from EB

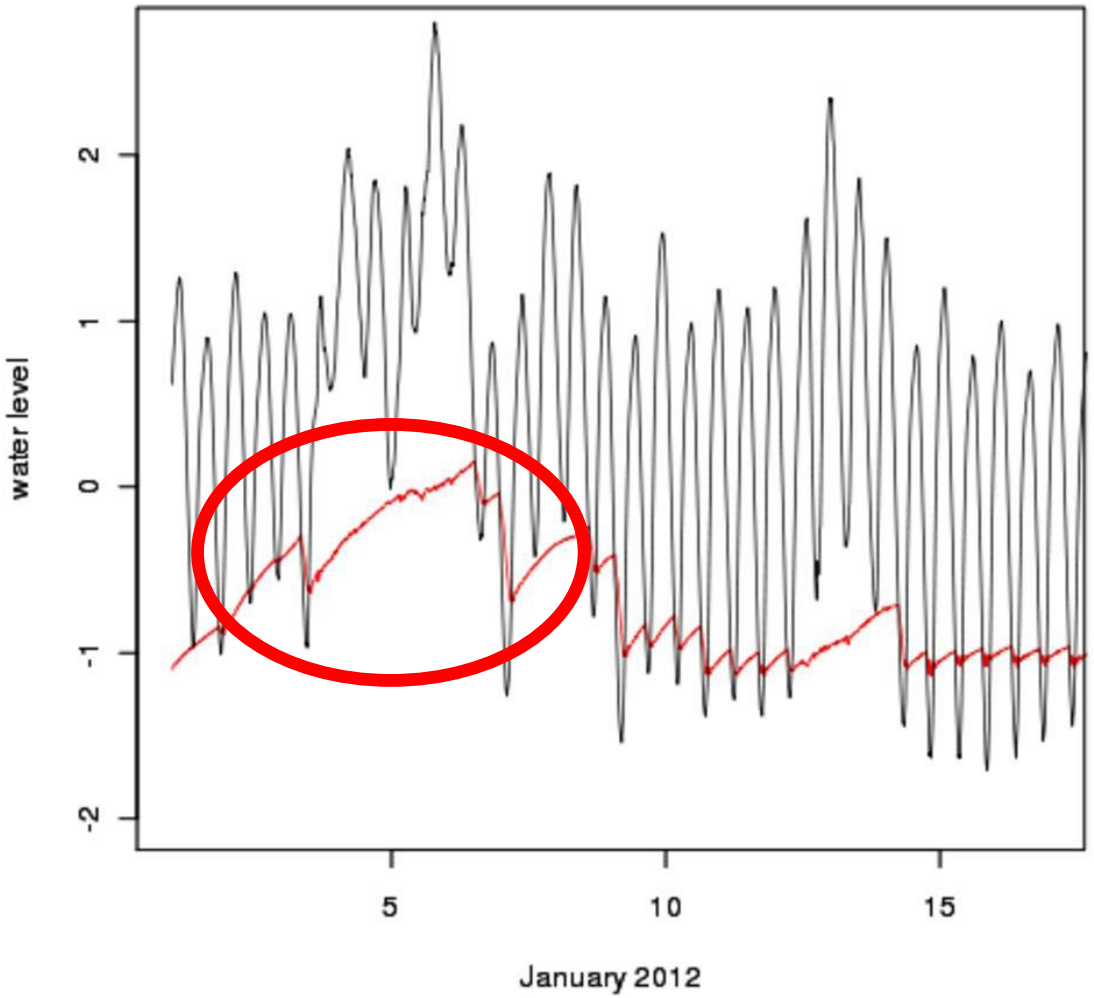
Compound flooding in Ravenna (Italy)



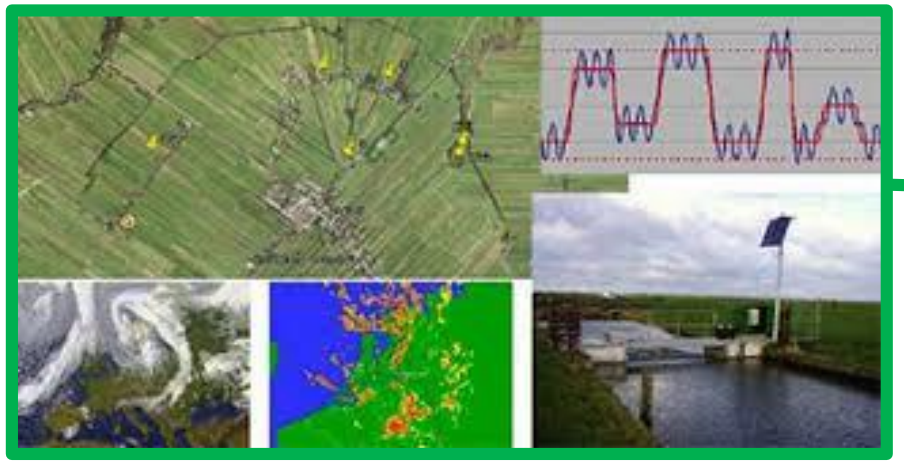
On 6th Feb 2015, along Ravenna's coast, river discharges were partially obstructed from draining into the sea by the storm surge, causing a compound flooding (**CF**).

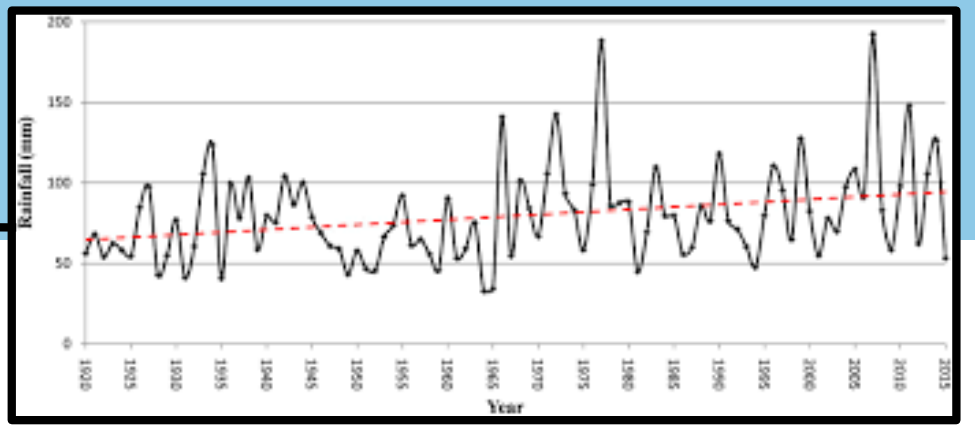
slide from EB

Near-flooding event 2012: a compound event



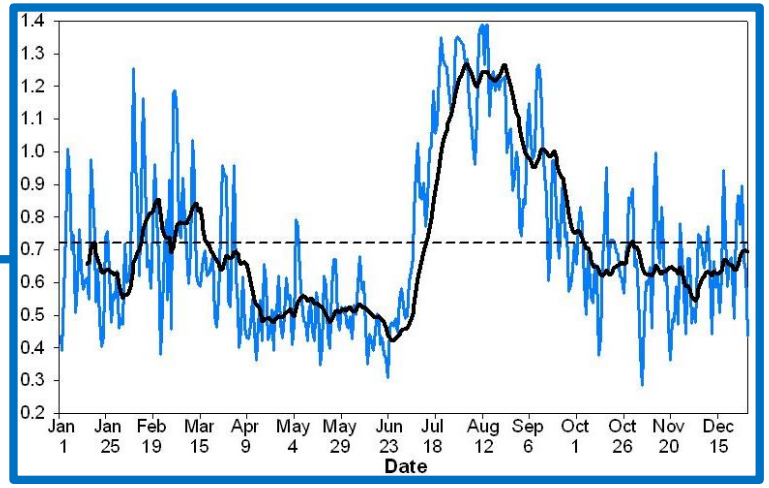
Computing infrastructure requirements



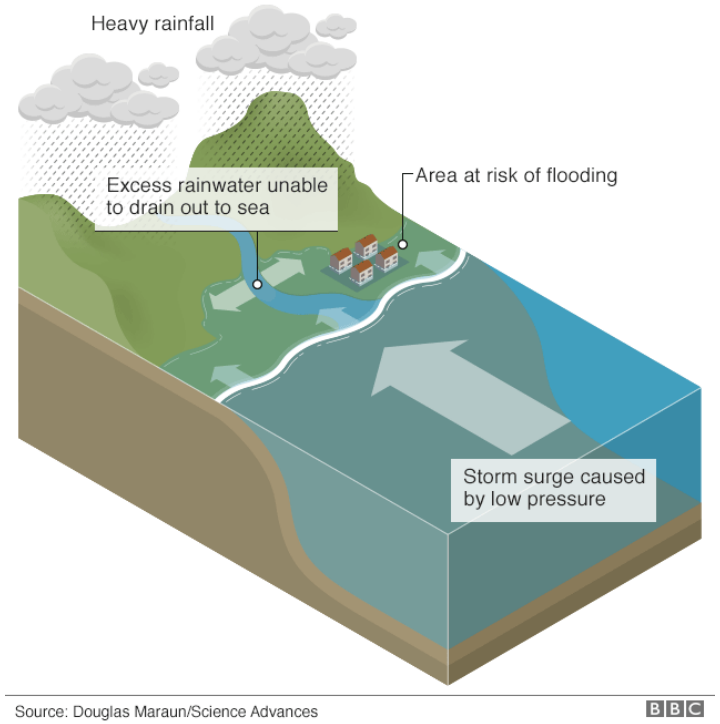


What about correlation characteristics between drivers?

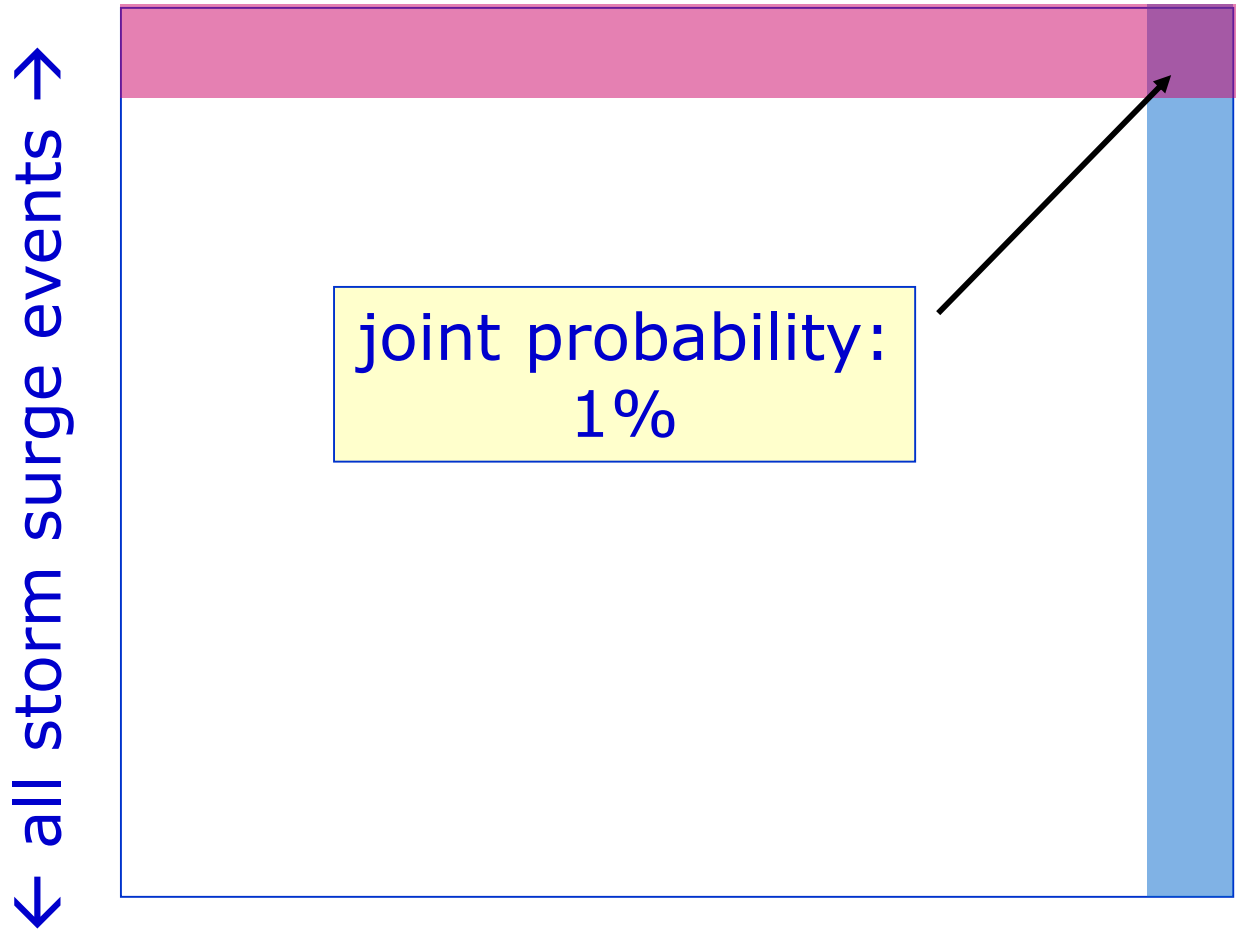
Statistics of time evolution of internal water fluctuations at short and long time scales



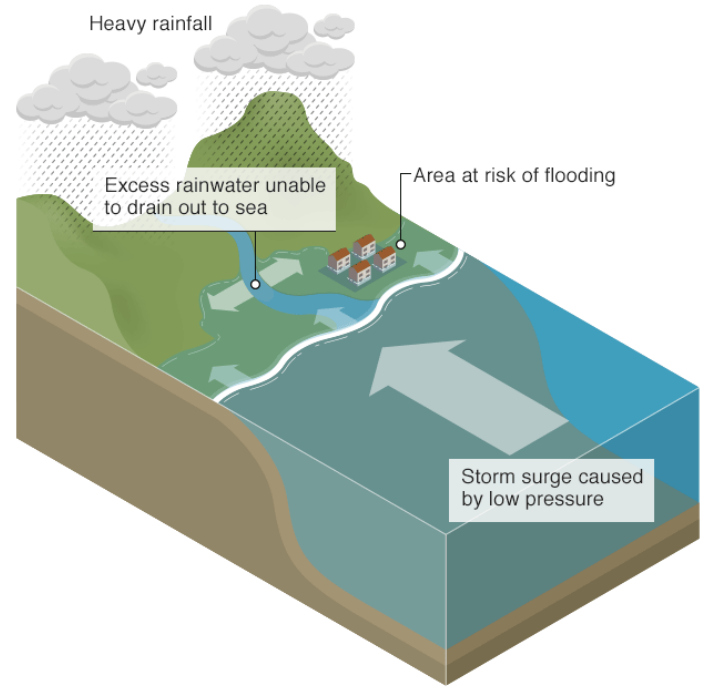
The concept of compound events



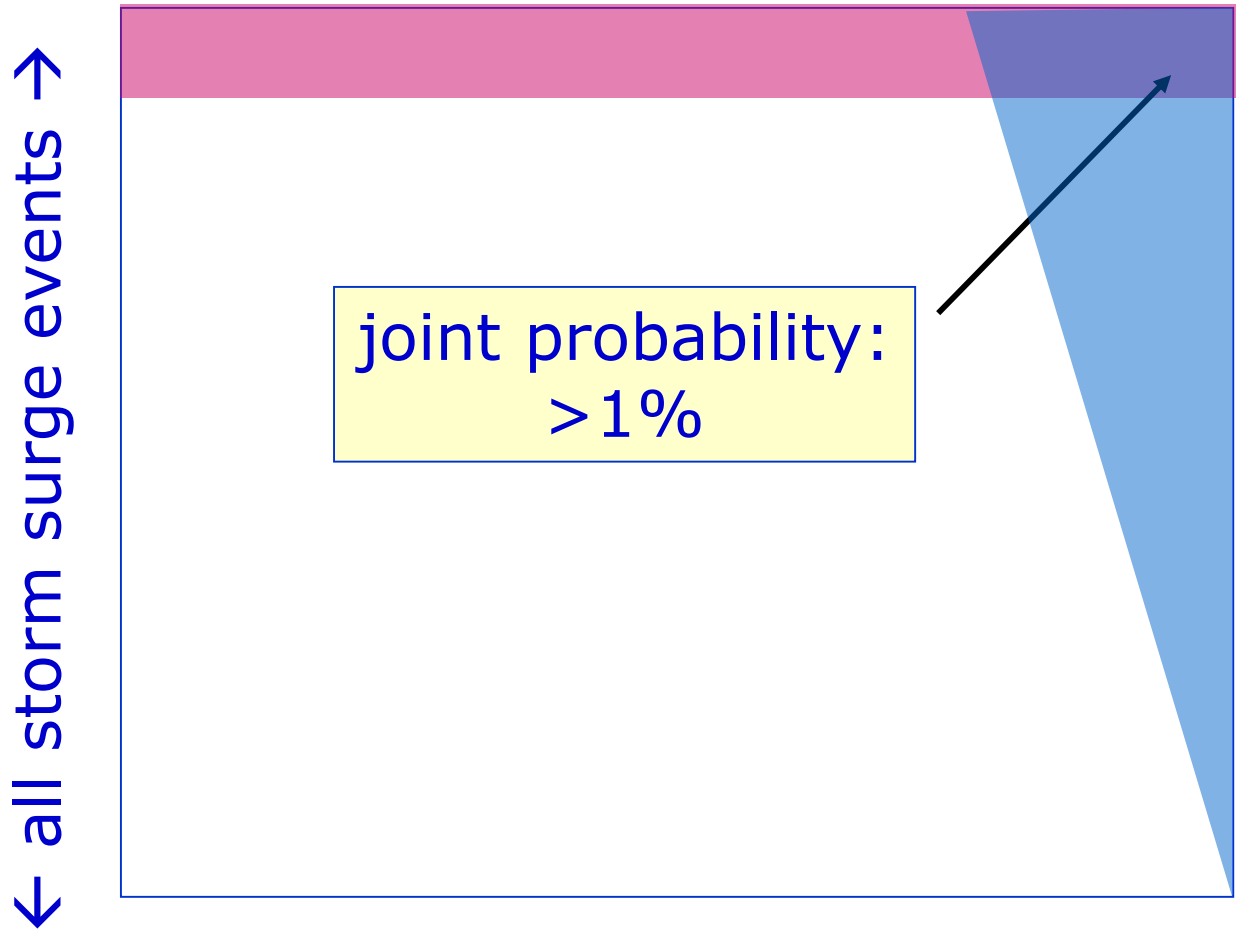
highest 10%



The concept of compound events

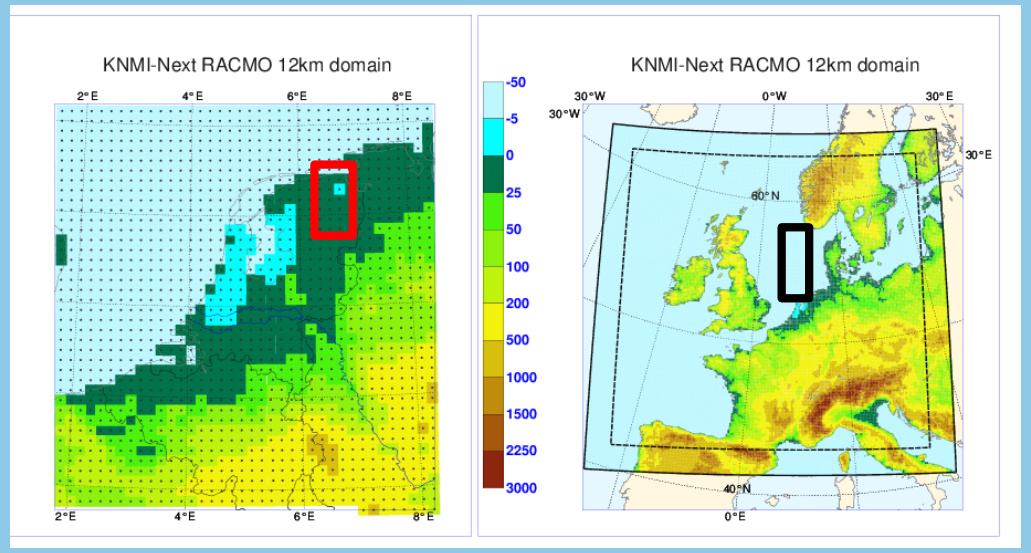


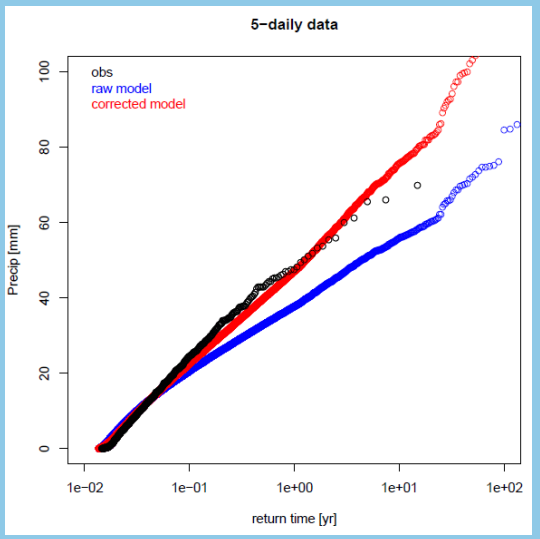
highest 10%



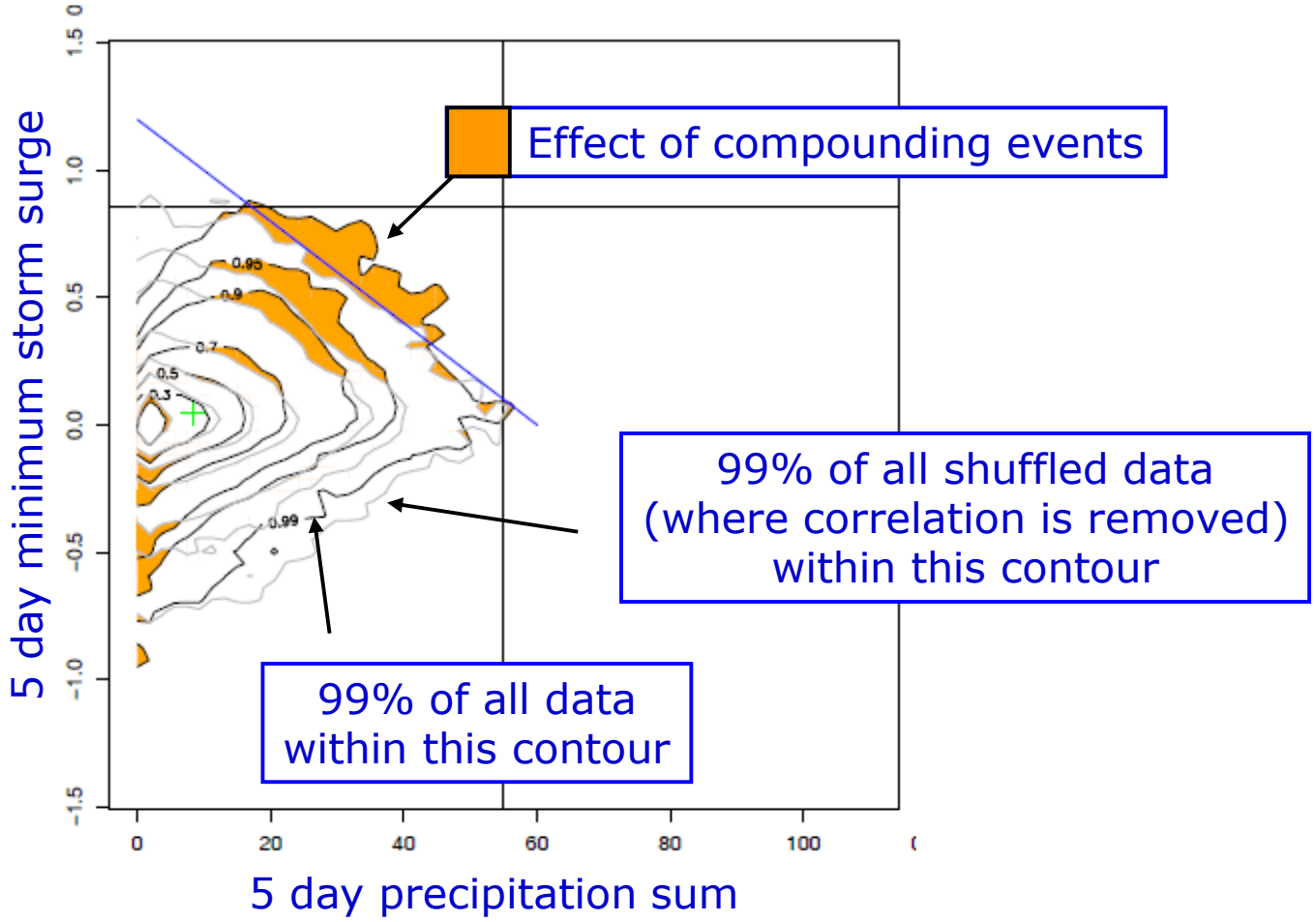
Analysis of compound events

- A regional climate model (RACMO2)
  - @12km
  - 1950 – 2000, 16 members = 800 yrs
  - precipitation averaged over target domain
  - storm surge derived from wind + astronomical tide
- Local precipitation observations
  - for statistical bias correction
- Hydrological model of Noorderzijlvest water system
  - including water management
  - to generate time series of inland water level

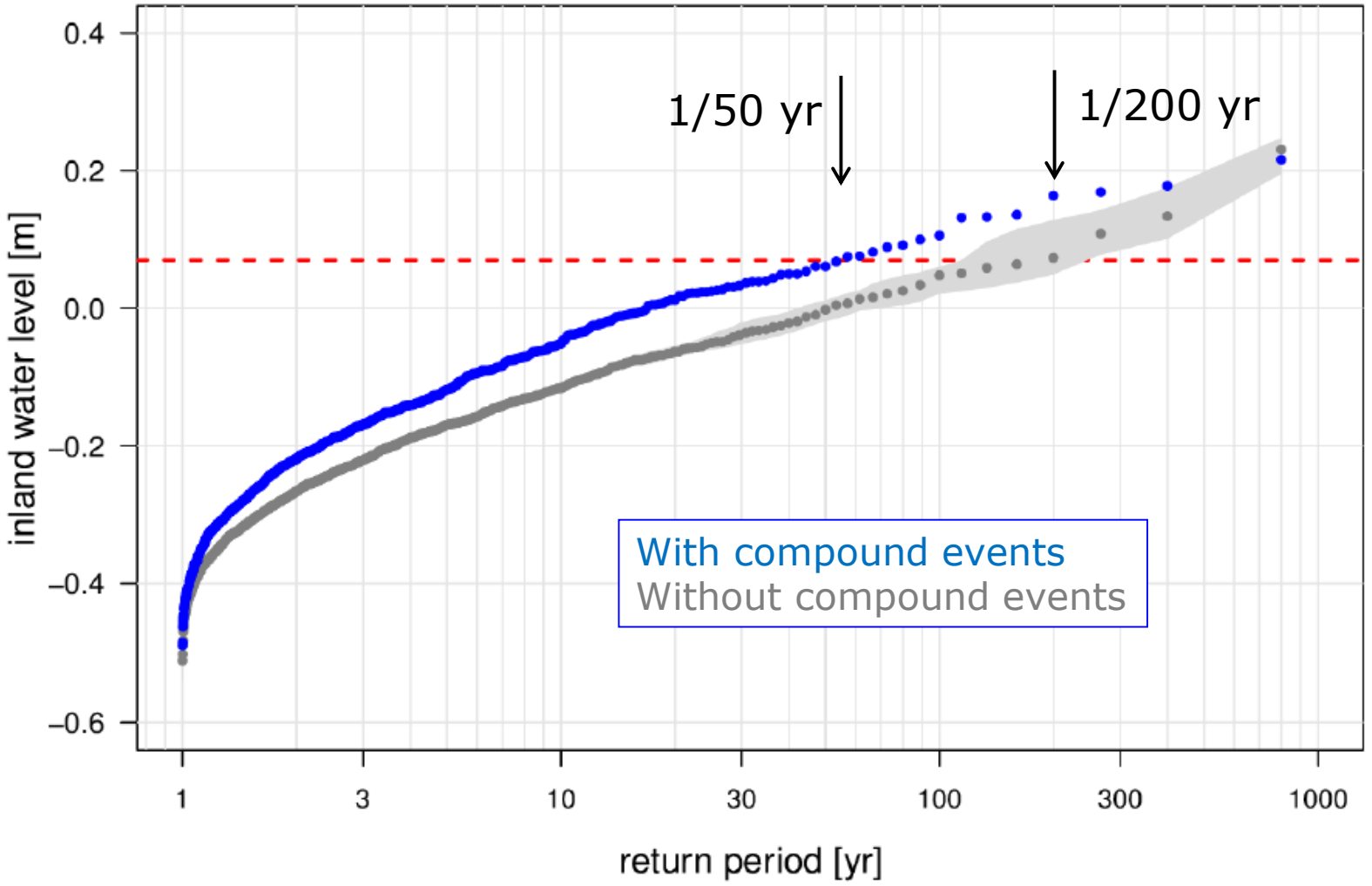




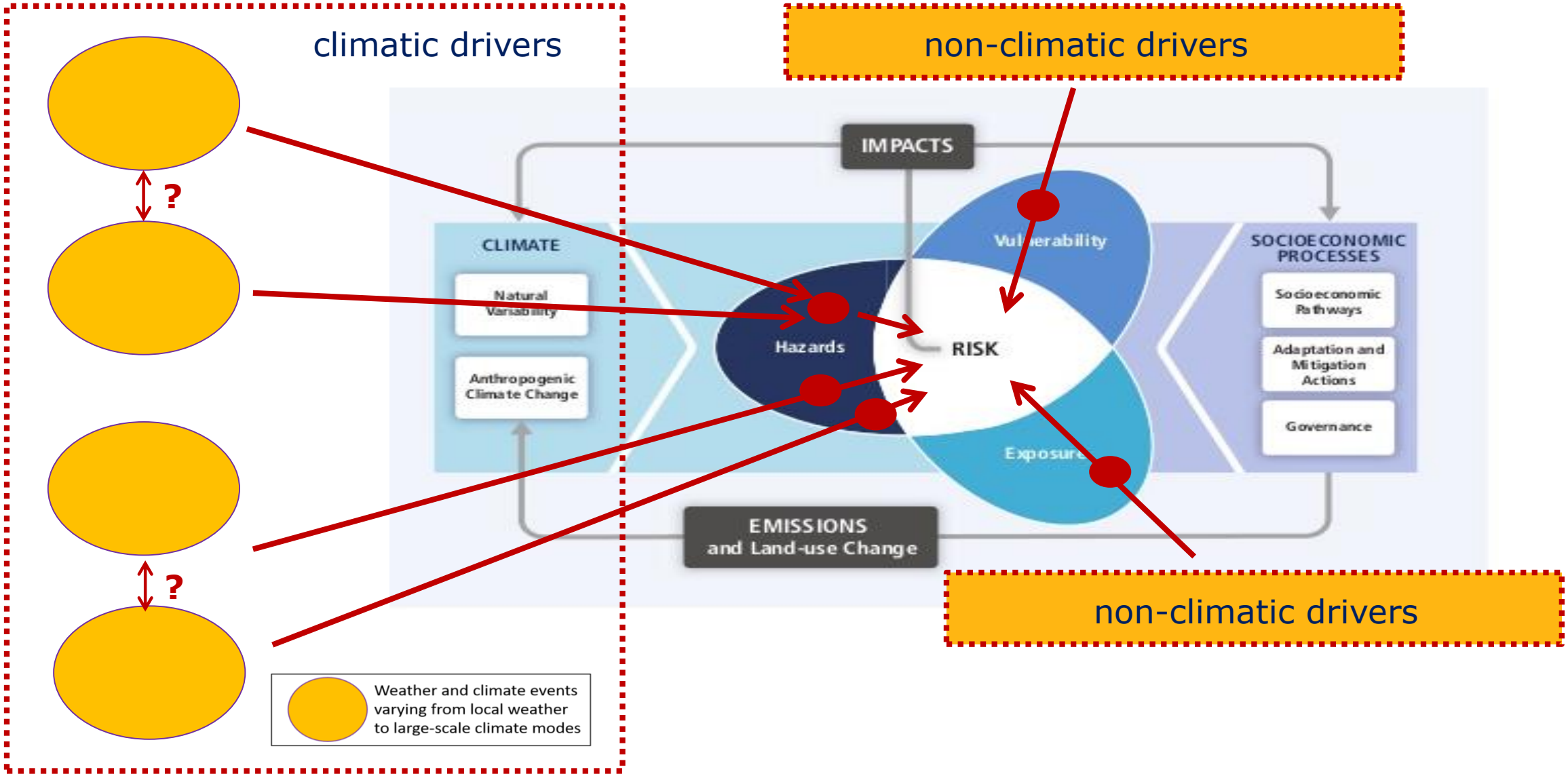
Compounding occurrence of storm surge and intense precipitation



Local water level at Lauwersmeer



The concept of risk



Compound events

Compound weather/climate events refer to the ***combination*** of ***multiple*** drivers and/or hazards that contributes to societal or environmental ***risk***.

nature climate change

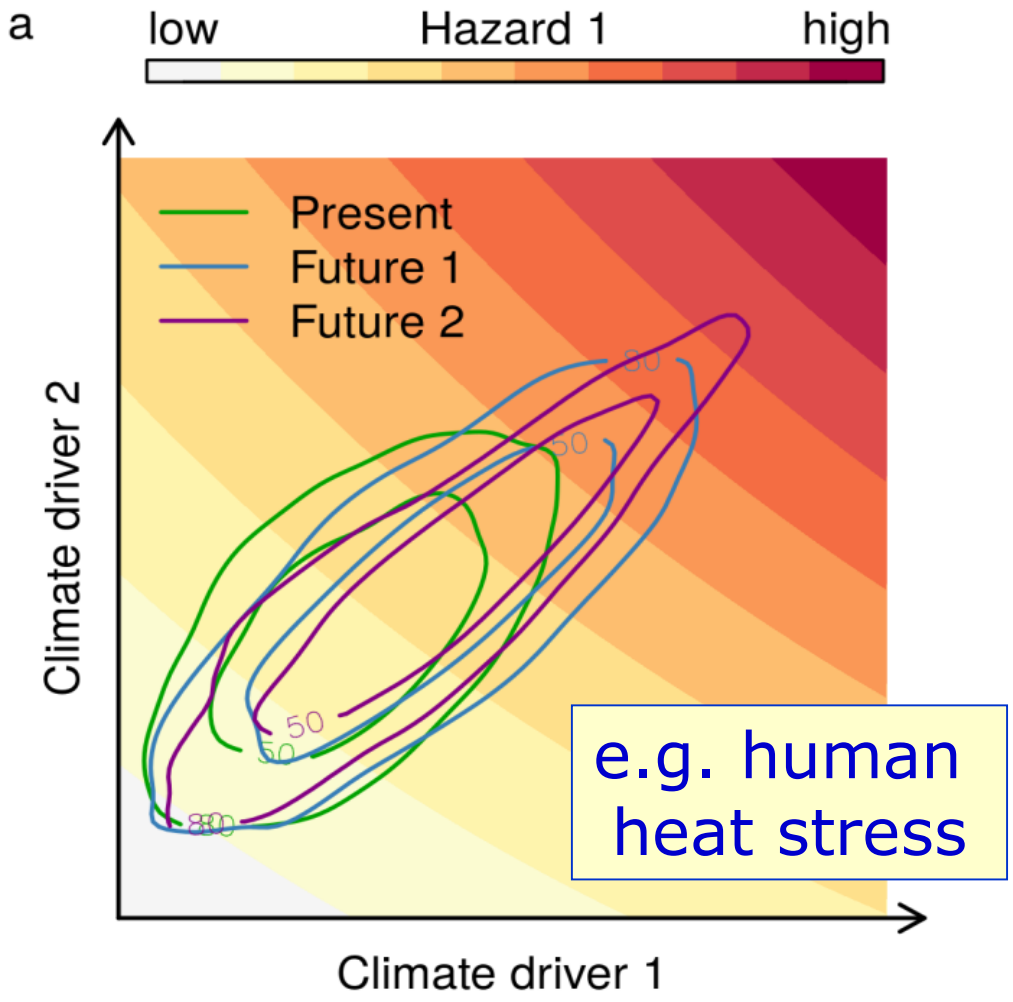
Future climate risk from compound events

Jakob Zscheischler[1*], Seth Westra[2], Bart J. J. M. van den Hurk[3,4], Sonia I. Seneviratne[1], Philip J. Ward[4], Andy Pitman[5], Amir AghaKouchak[6], David N. Bresch[7,8], Michael Leonard[2], Thomas Wahl[9] and Xuebin Zhang[10]

Floods, wildfires, heatwaves and droughts often result from a combination of interacting physical processes across multiple spatial and temporal scales. The combination of processes (climate drivers and hazards) leading to a significant impact is referred to as a 'compound event'. Traditional risk assessment methods typically only consider one driver and/or hazard at a time, potentially leading to underestimation of risk, as the processes that cause extreme events often interact and are spatially and/or temporally dependent. Here we show how a better understanding of compound events may improve projections of potential high-impact events, and can provide a bridge between climate scientists, engineers, social scientists, impact modellers and decision-makers, who need to work closely together to understand these complex events.

Zscheischler et al, NCC 2018

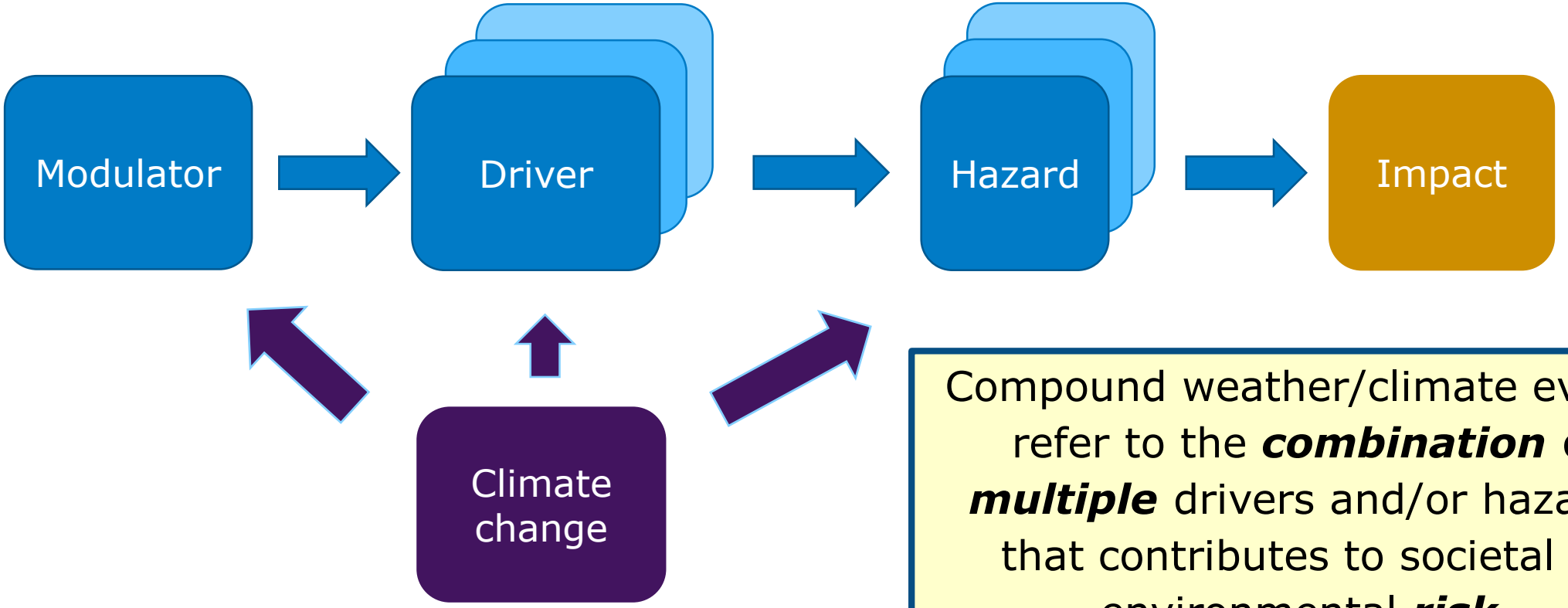
Impact varies with combination of drivers



Examples

Drought	Precipitation, evapotranspiration, historic evolution of soil moisture, temperature
Heat stress	Diurnal cycle of temperature, humidity
Fire risk	Temperature, precipitation, relative humidity, wind, lightning
Coastal flooding	Storm surge, precipitation, discharge
Concurrent phenomena	wind, precipitation, temperature, air pollution, ...

Elements of a compound event

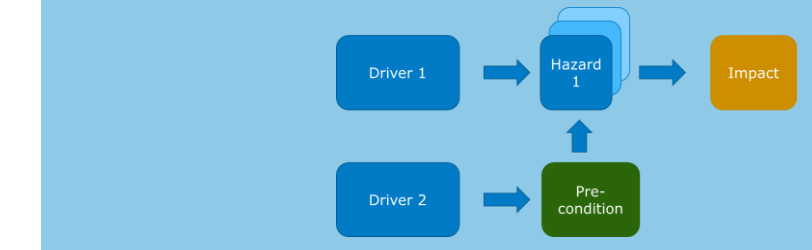


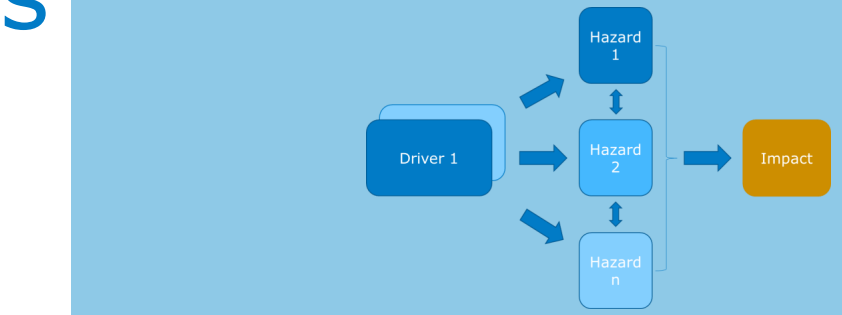
Compound weather/climate events refer to the ***combination*** of ***multiple*** drivers and/or hazards that contributes to societal or environmental ***risk***.

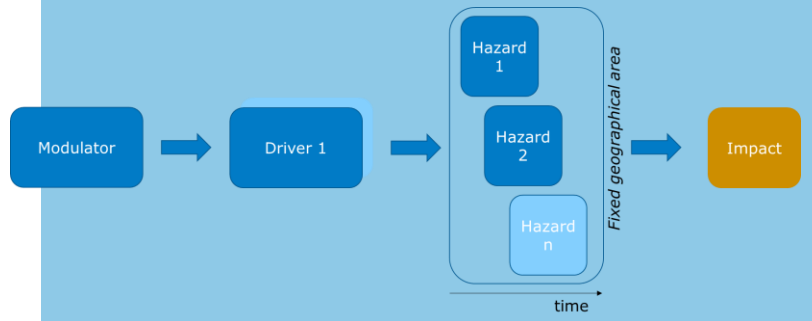
slide from JZ

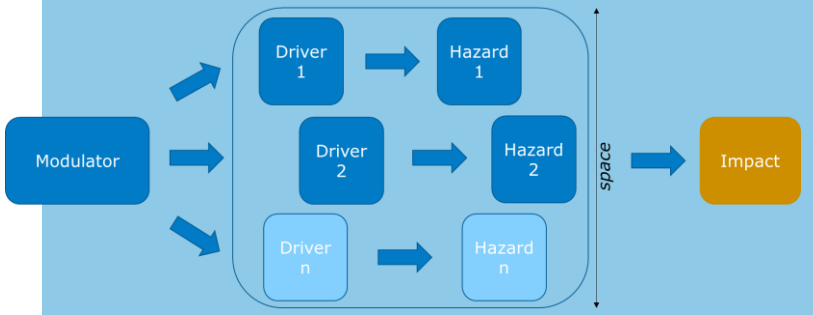
Four types of compound events

1. Preconditioning
2. Concurrent events
3. Temporally compounding
4. Spatially compounding









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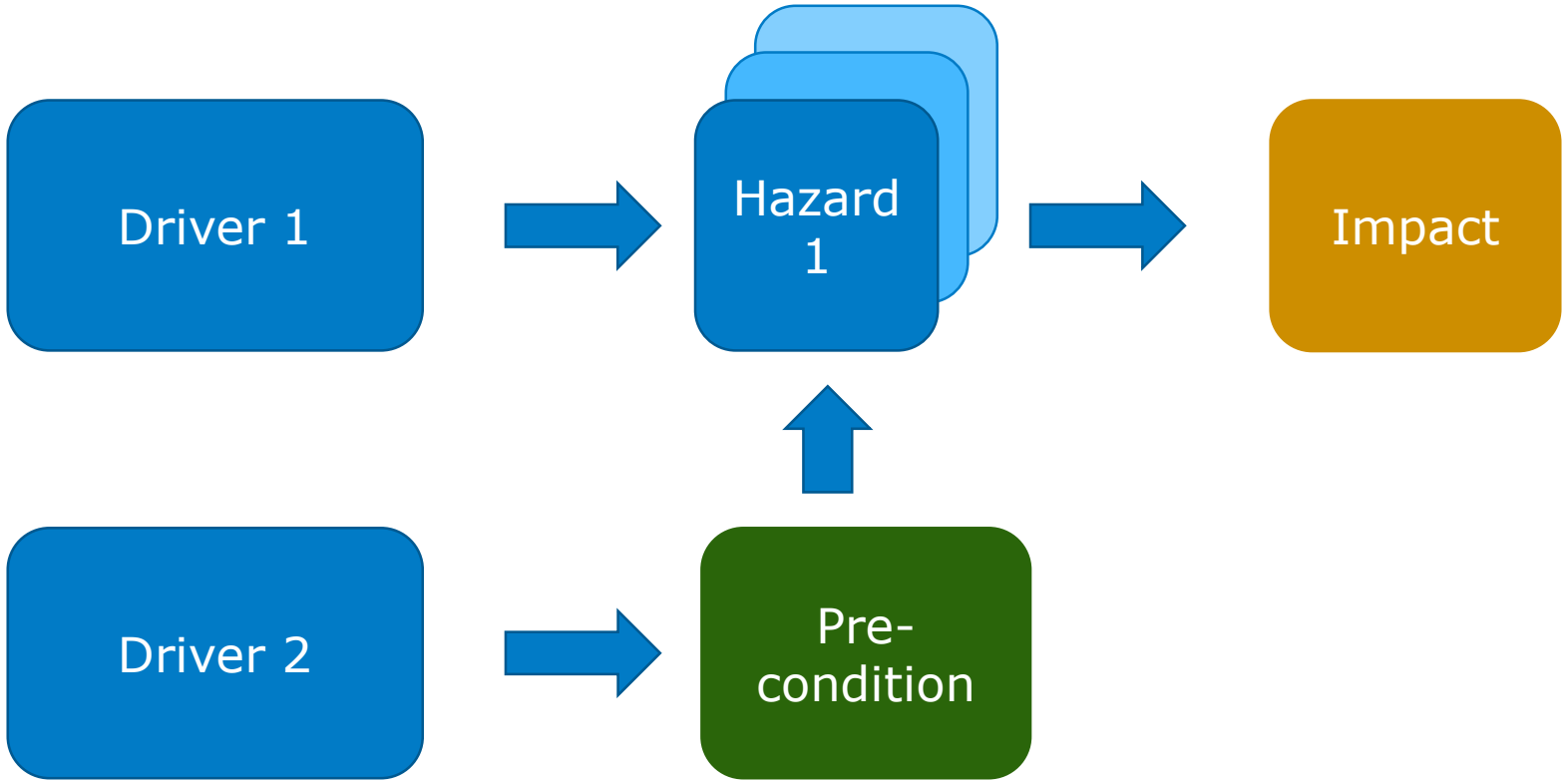
1. Preconditioning



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“False” spring

Regularly causing large-scale damage to natural vegetation and crops in temperate regions.

Warm late winter: creates *precondition*

Frost in early spring: *hazard*

Damaged sugar maple trees

slide from JZ

Hufkens et al. (2012) *Glob. Ch. Biol.*

Rain on snow events

Important flood-producing events in the high latitudes and mountainous areas.

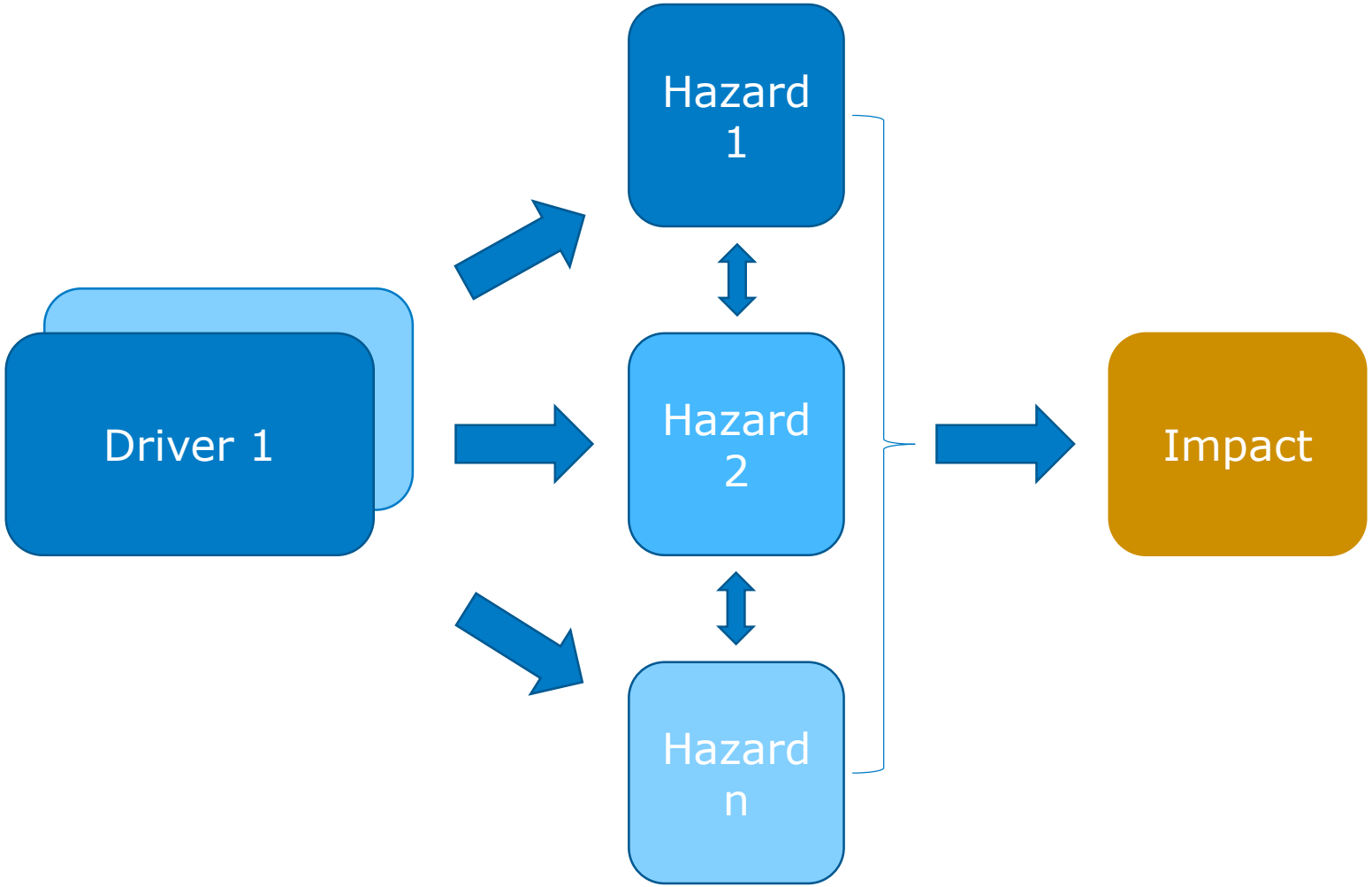
Snow-covered surface: *precondition*

Rain: *hazard*

slide from JZ

https://www.thegazette.com/subject/news/public-safety/national-weather-service-issues-flood-watch-for-cedar-rapids-iowa-city-eastern-iowa-wednesday-thursday-melting-snow-rain-20190311

2. Concurrent events



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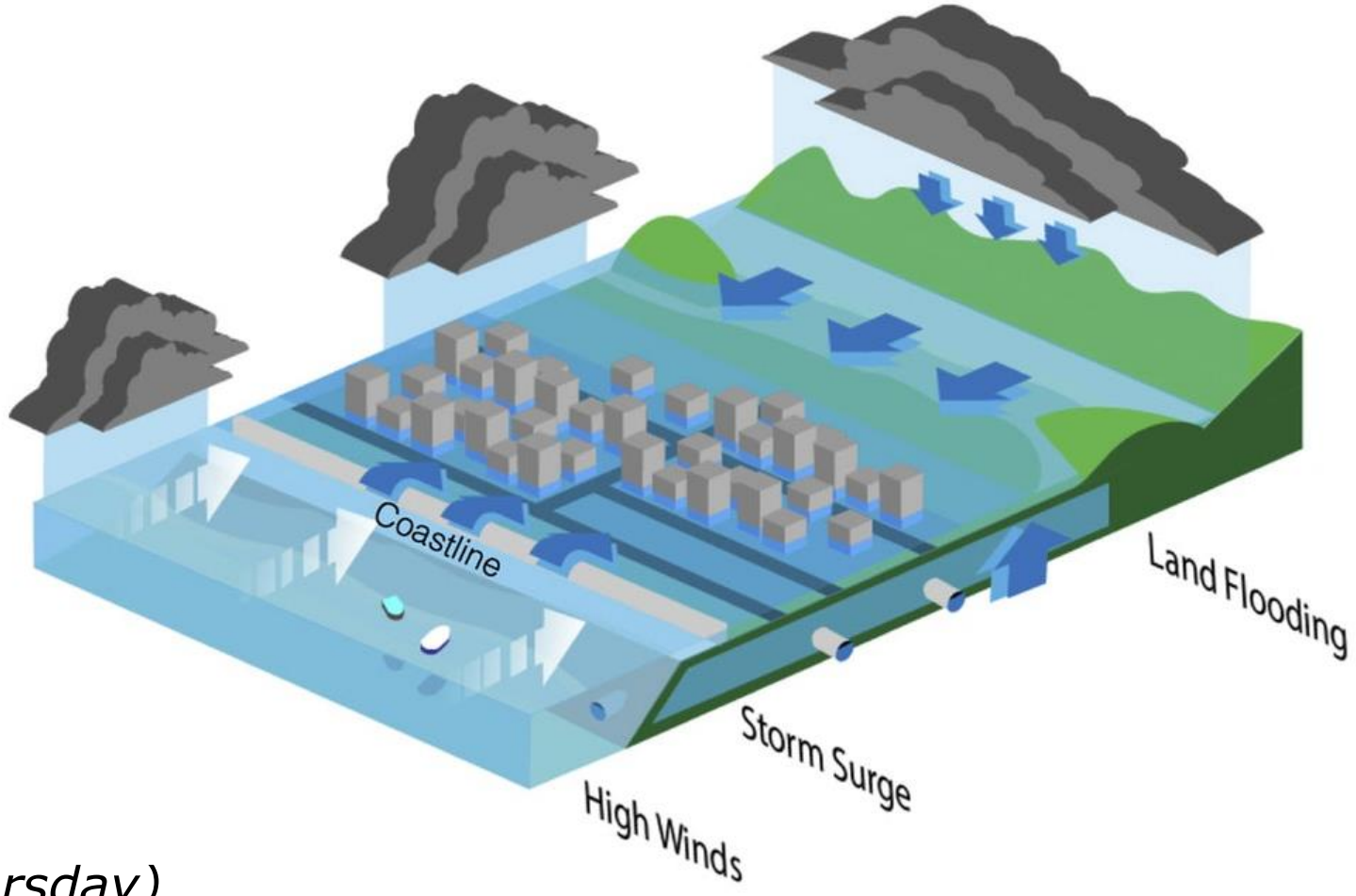
Compound flooding

Common driver: storms, tropical cyclones, atmospheric rivers, etc.

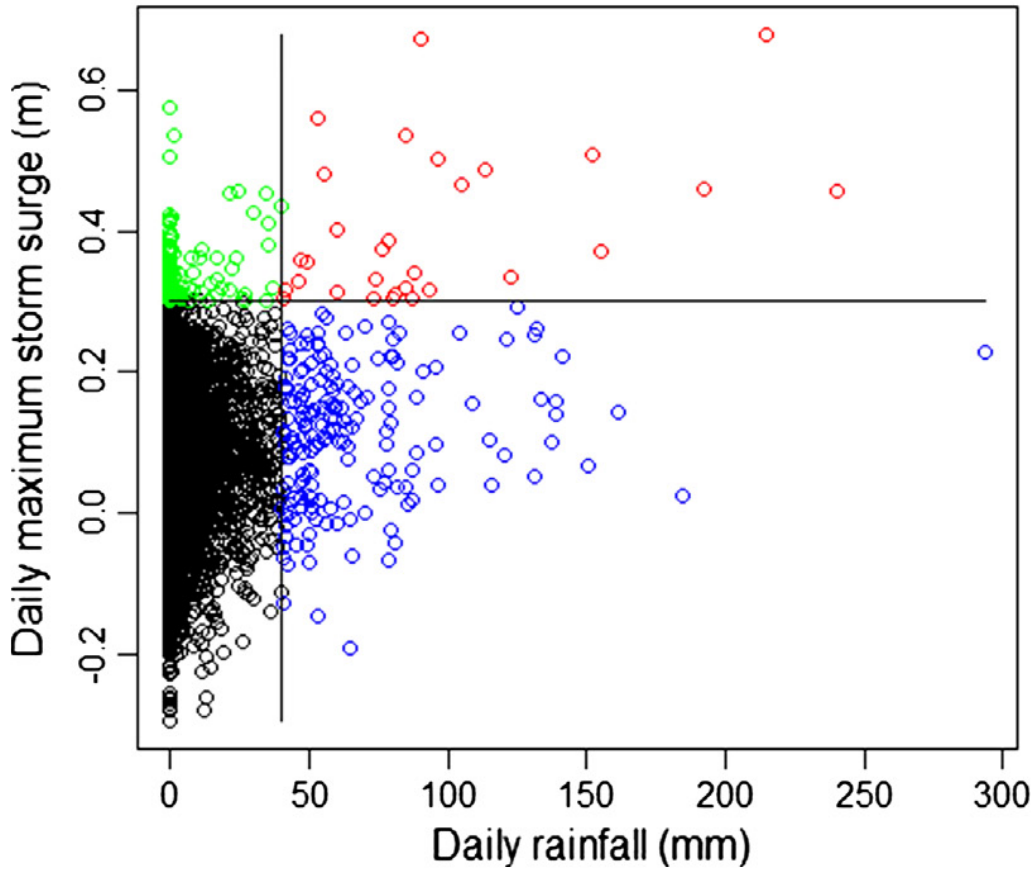


See 2nd lecture on CE's (Thursday)

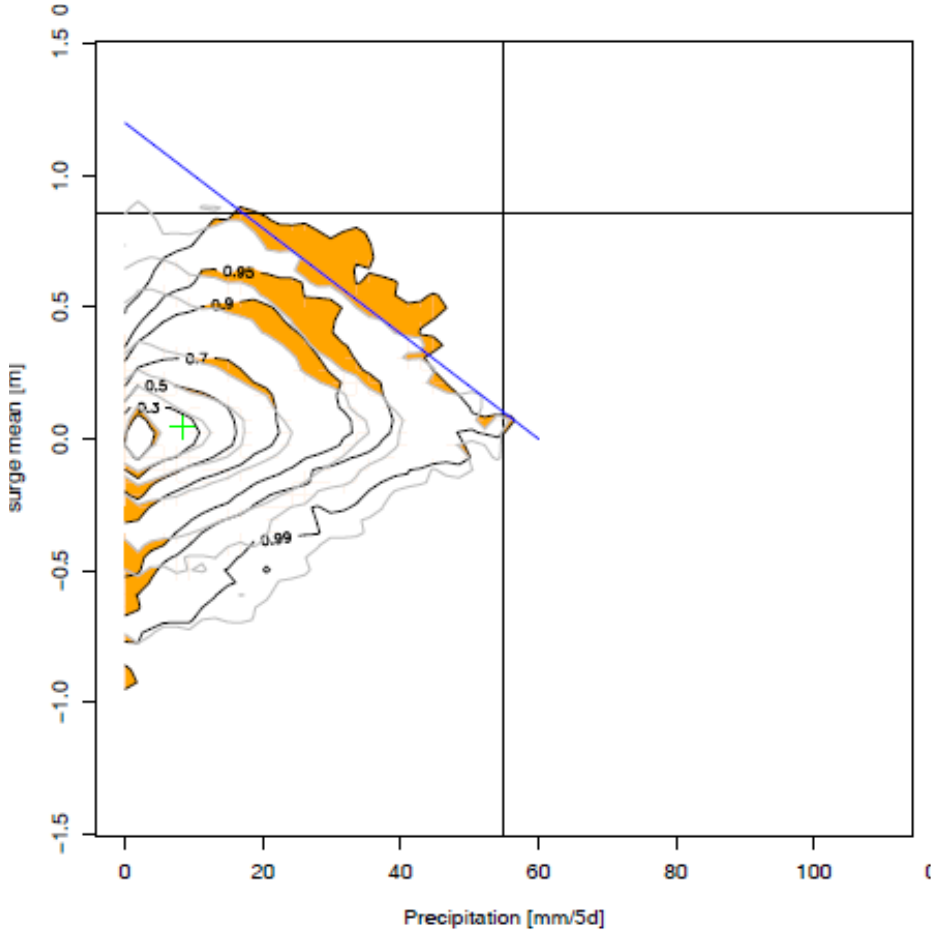
slide from JZ

http://nmdportfolios.org/tscontras/2015/12/21/asap-project-graphics/

Various types of dependence

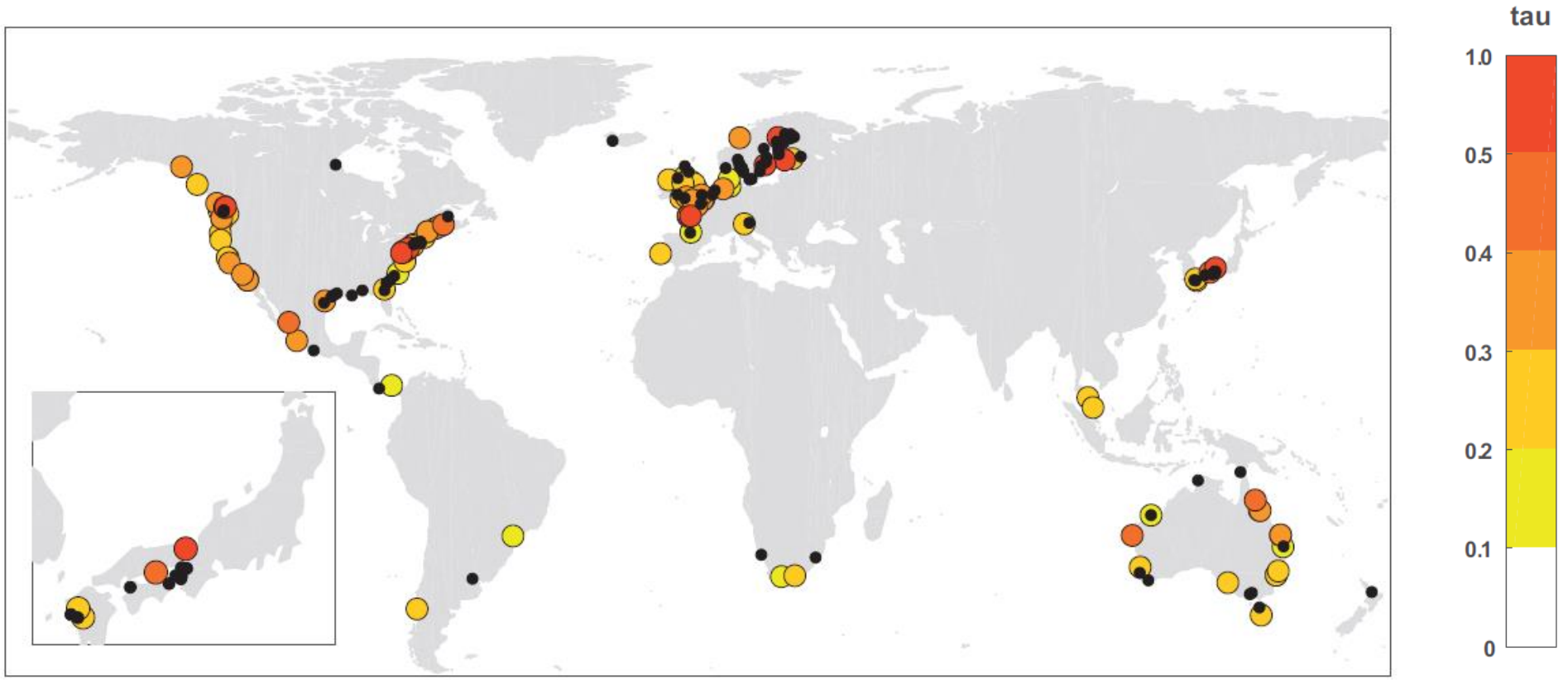


Zheng et al. (2013) *J. of Hydrology*



Van den Hurk et al. (2015) *ERL*

Correlation is highly variable in space



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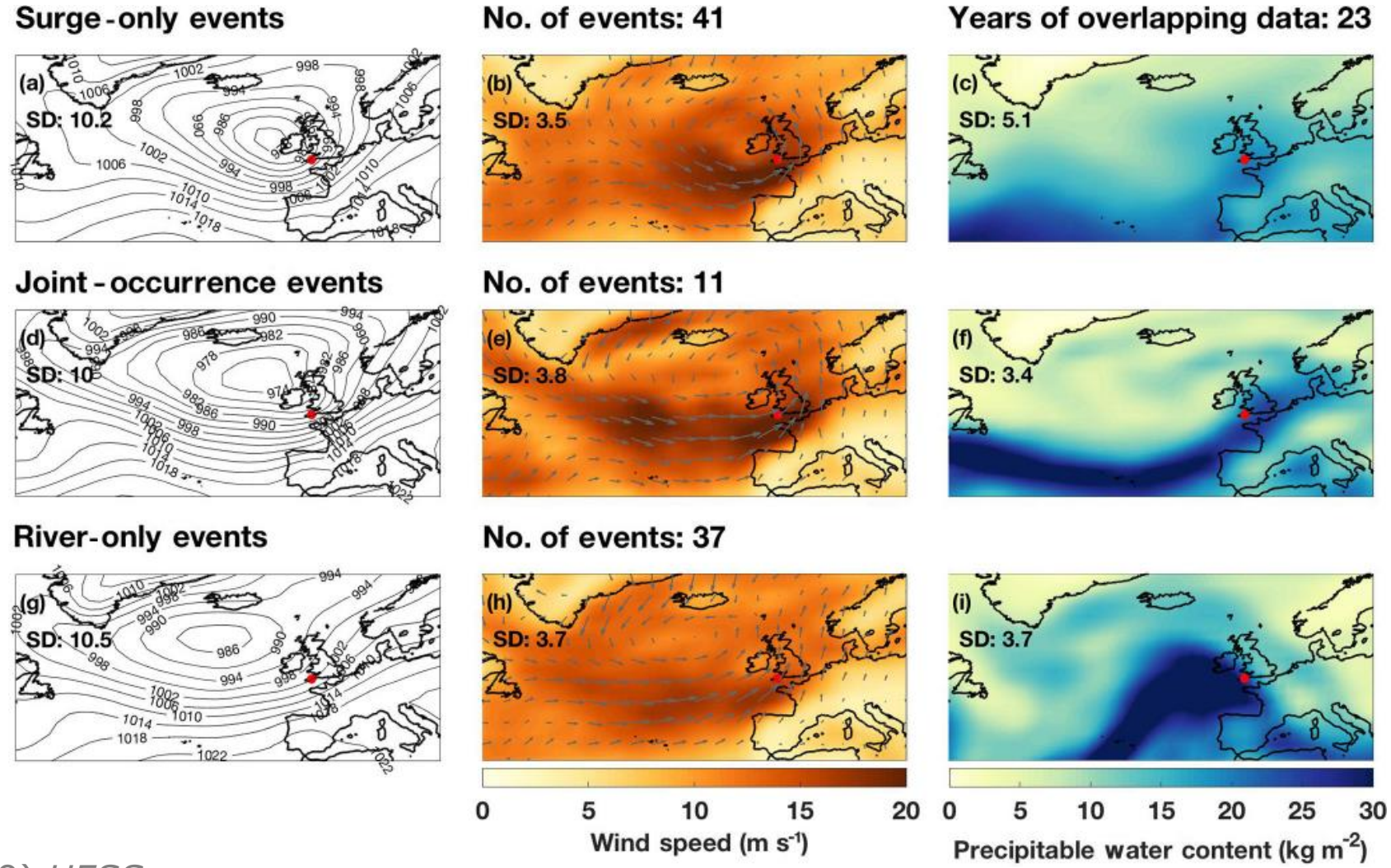
Ward et al. (2018) *ERL*

Separate the drivers – Compositing

Events at Devonport, UK



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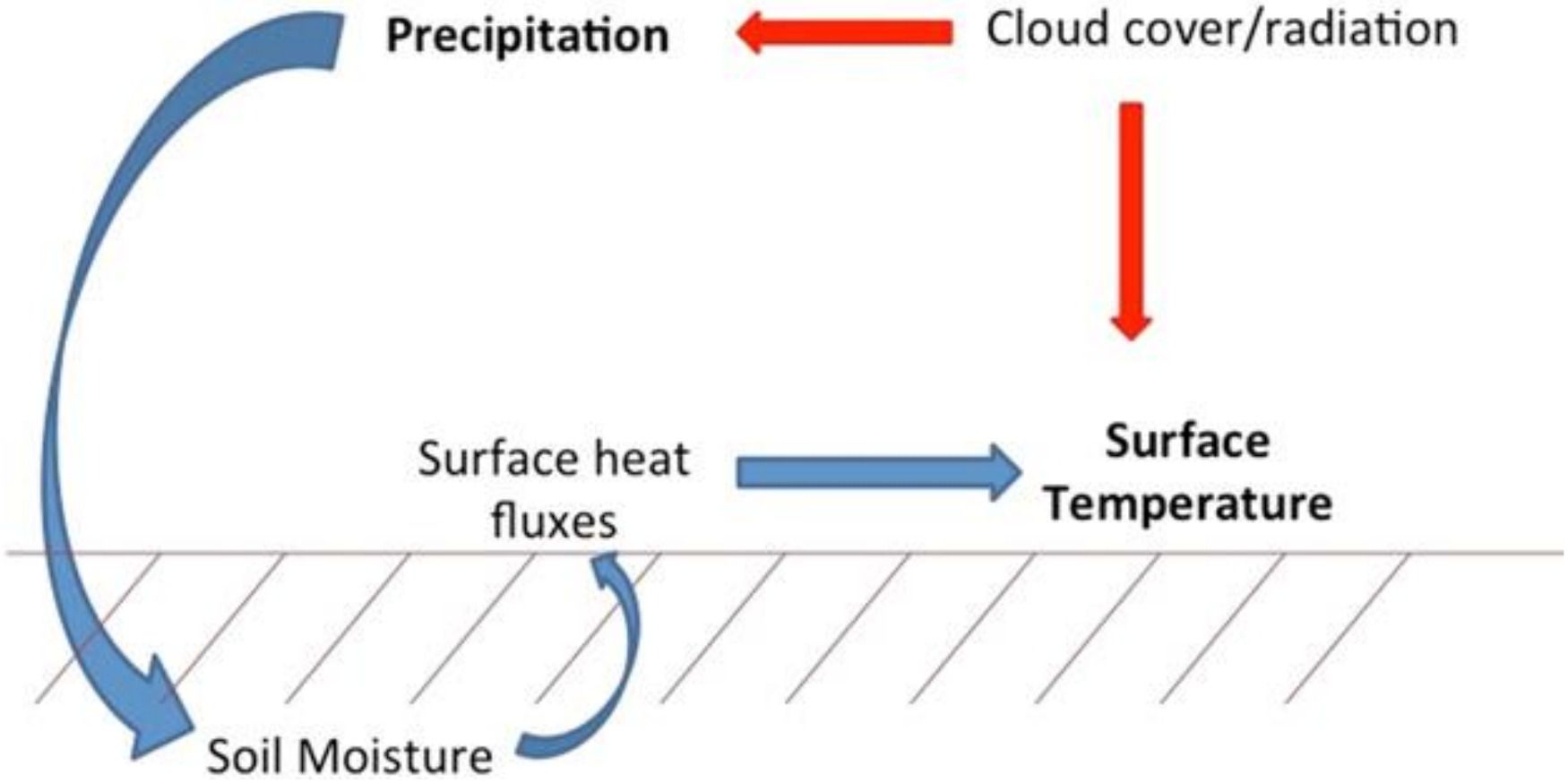
Hendry et al. (2019) *HESS*

Concurrent drought and heat



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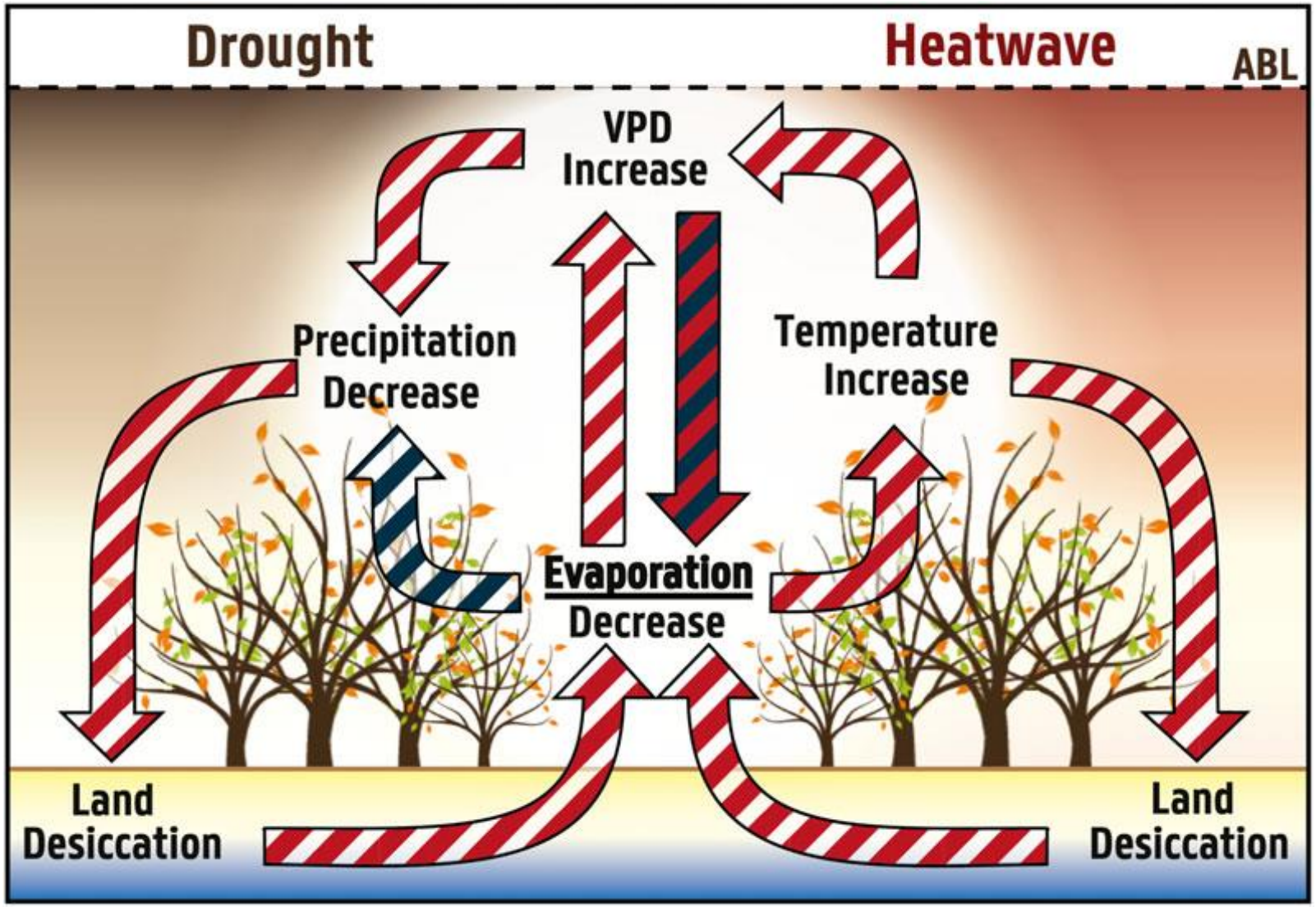
Berg et al. (2015) *J. Clim.*

Drought-heat feedbacks



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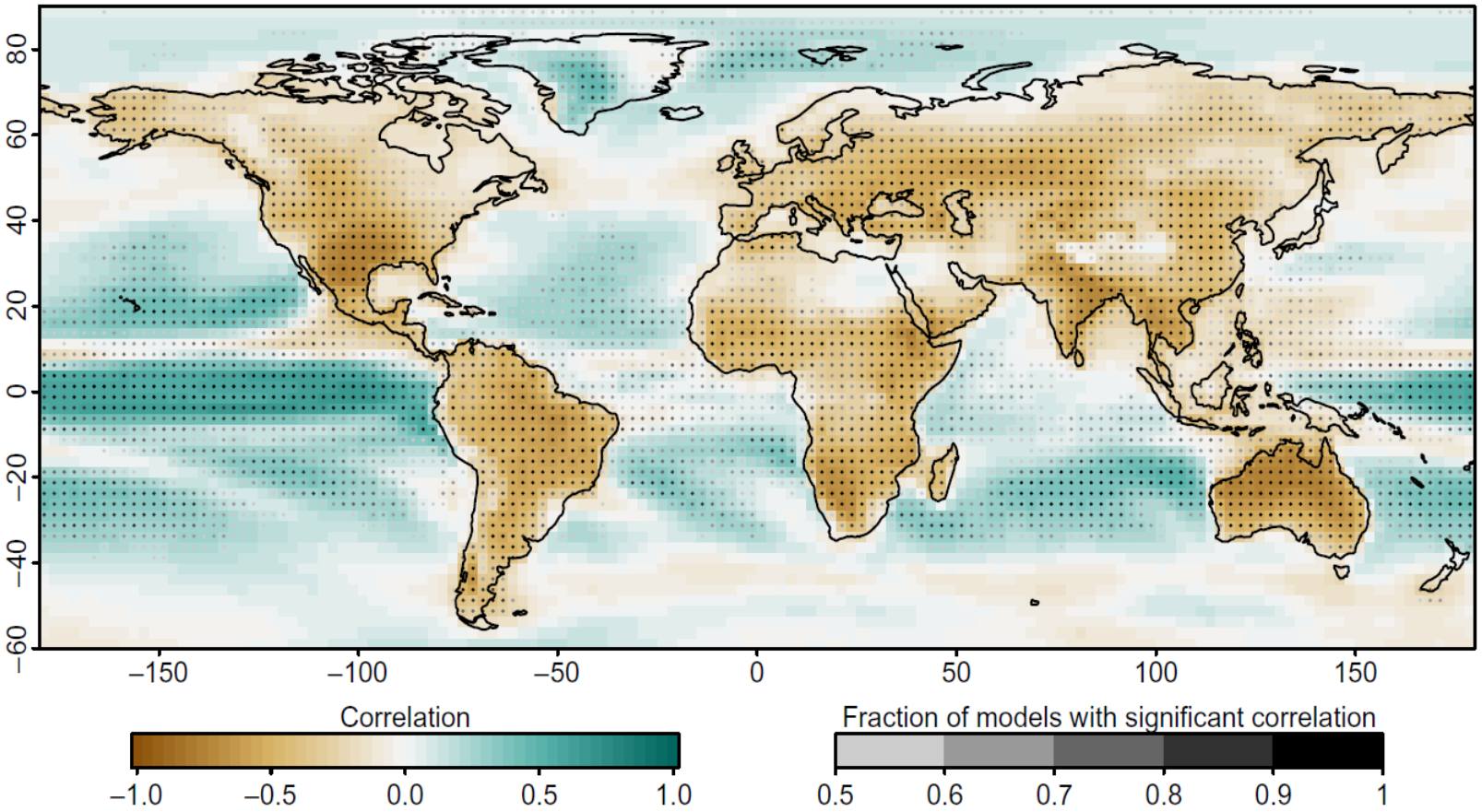
Miralles et al. (2018) *Ann. N. Y. Acad. Sci.*

Combined high temperature-low precipitation

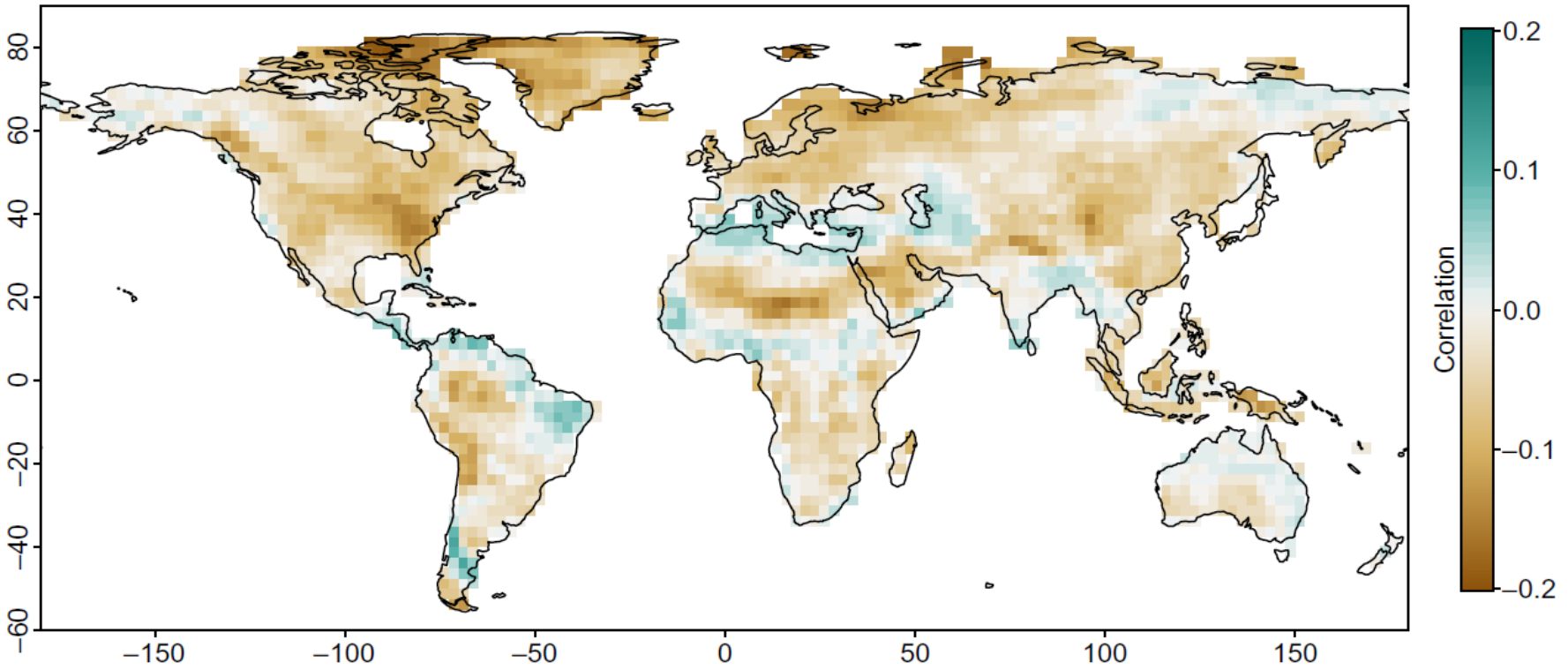
- Correlation between summer temperature and precipitation (CMIP5)



Zscheischler & Seneviratne, *Science Advances* (2017)

Change in dependence

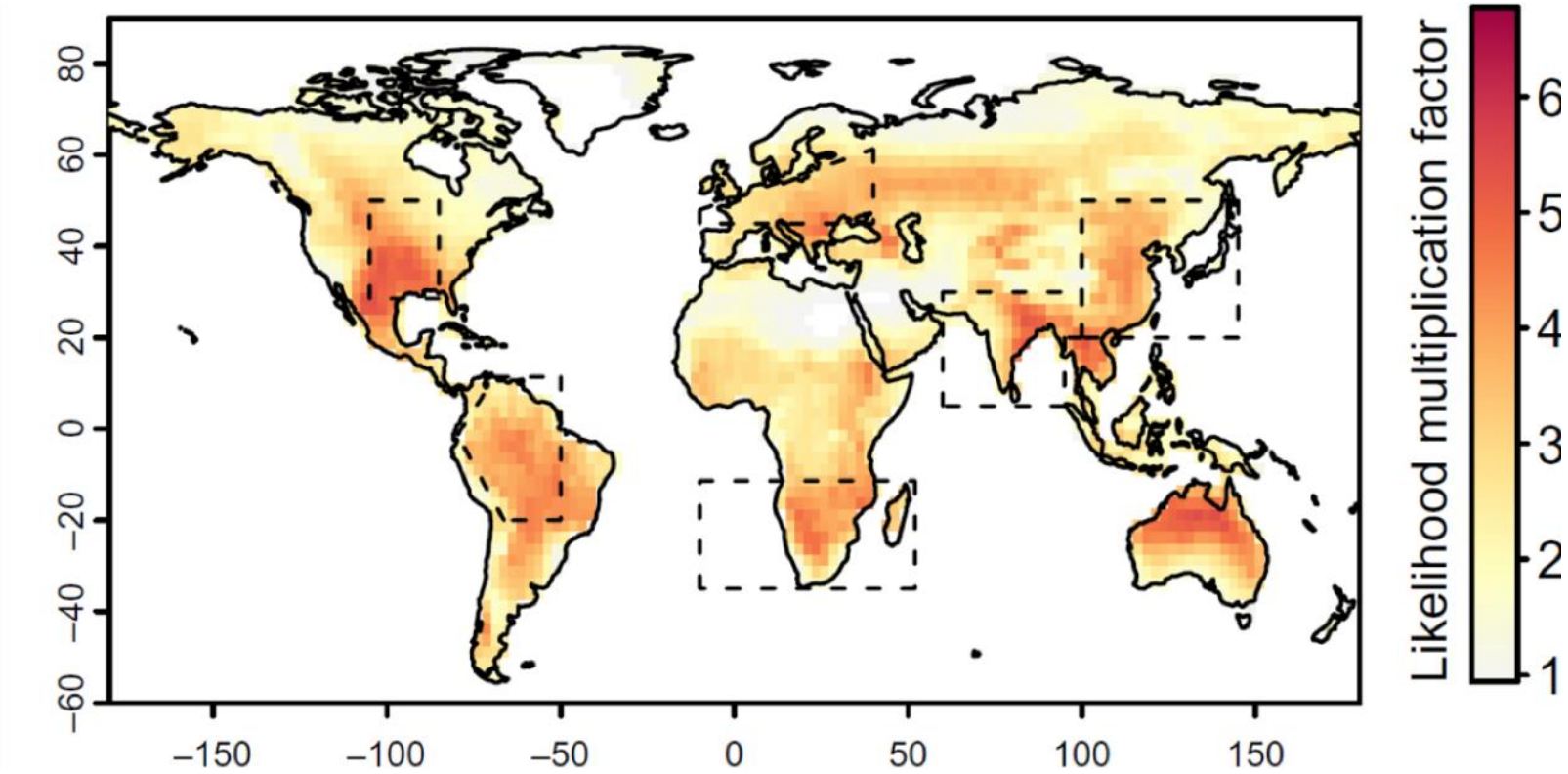
- Change in correlation 1870-1969 and 2001-2100 (RCP8.5)



Zscheischler & Seneviratne, *Science Advances* (2017)

Likelihood of concurrent hot and dry summers

- How much more likely is the combination of 10% highest temperature and 10% lowest precipitation?



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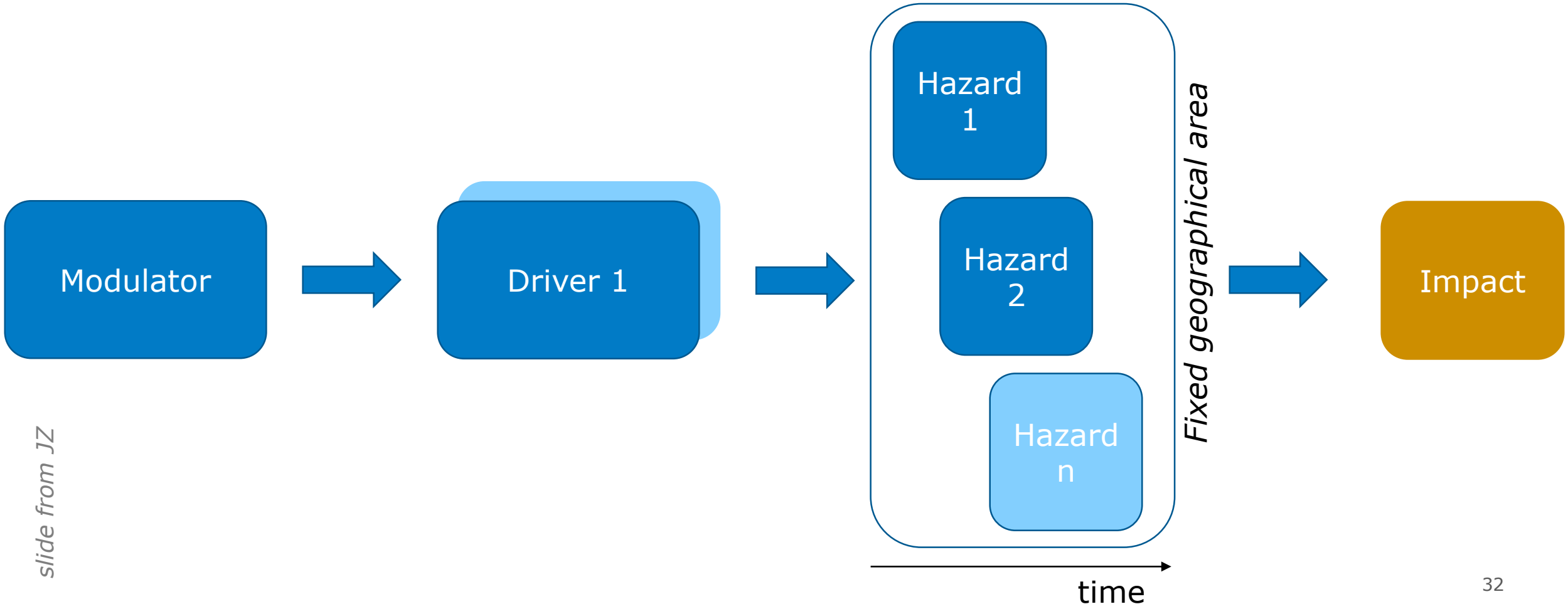
Zscheischler & Seneviratne (2017) *Science Advances*

3. Temporally compounding



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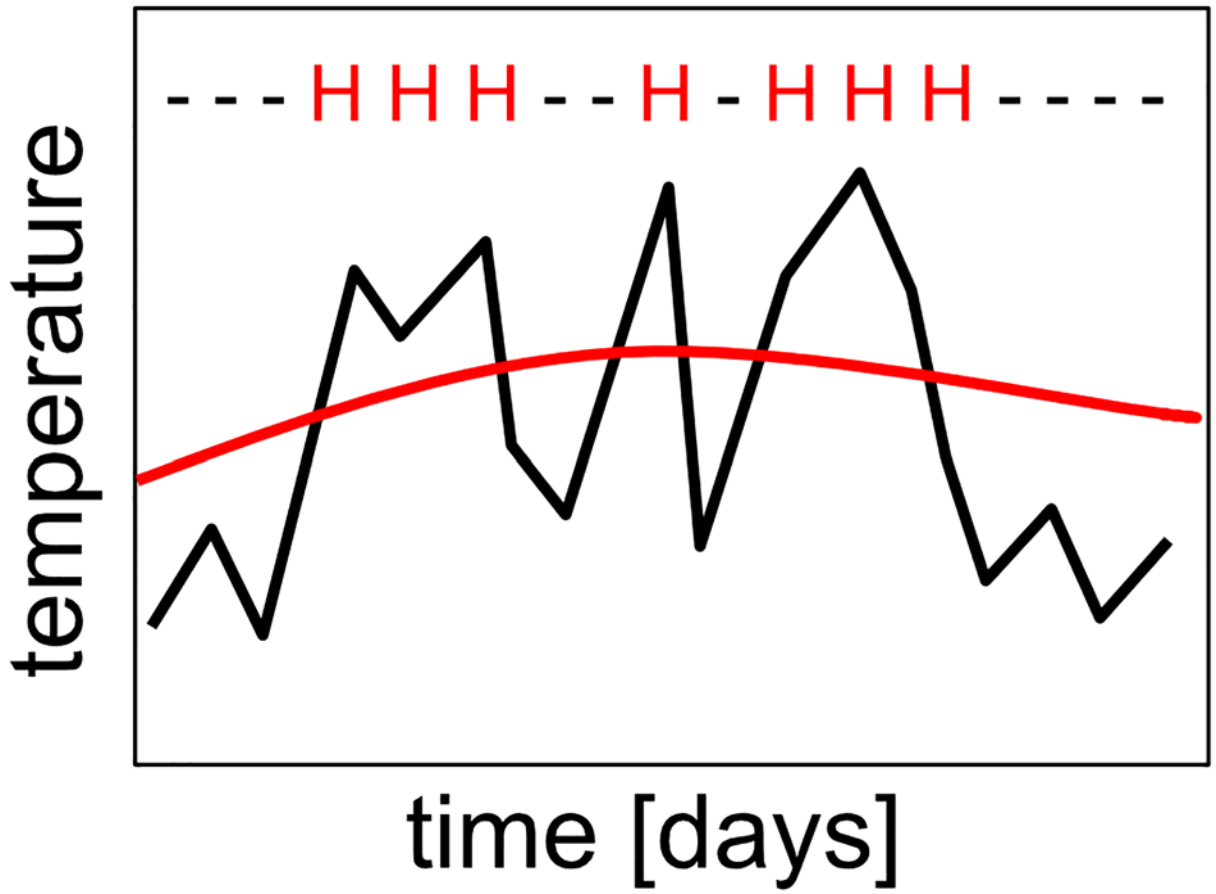
Sequence of heatwaves



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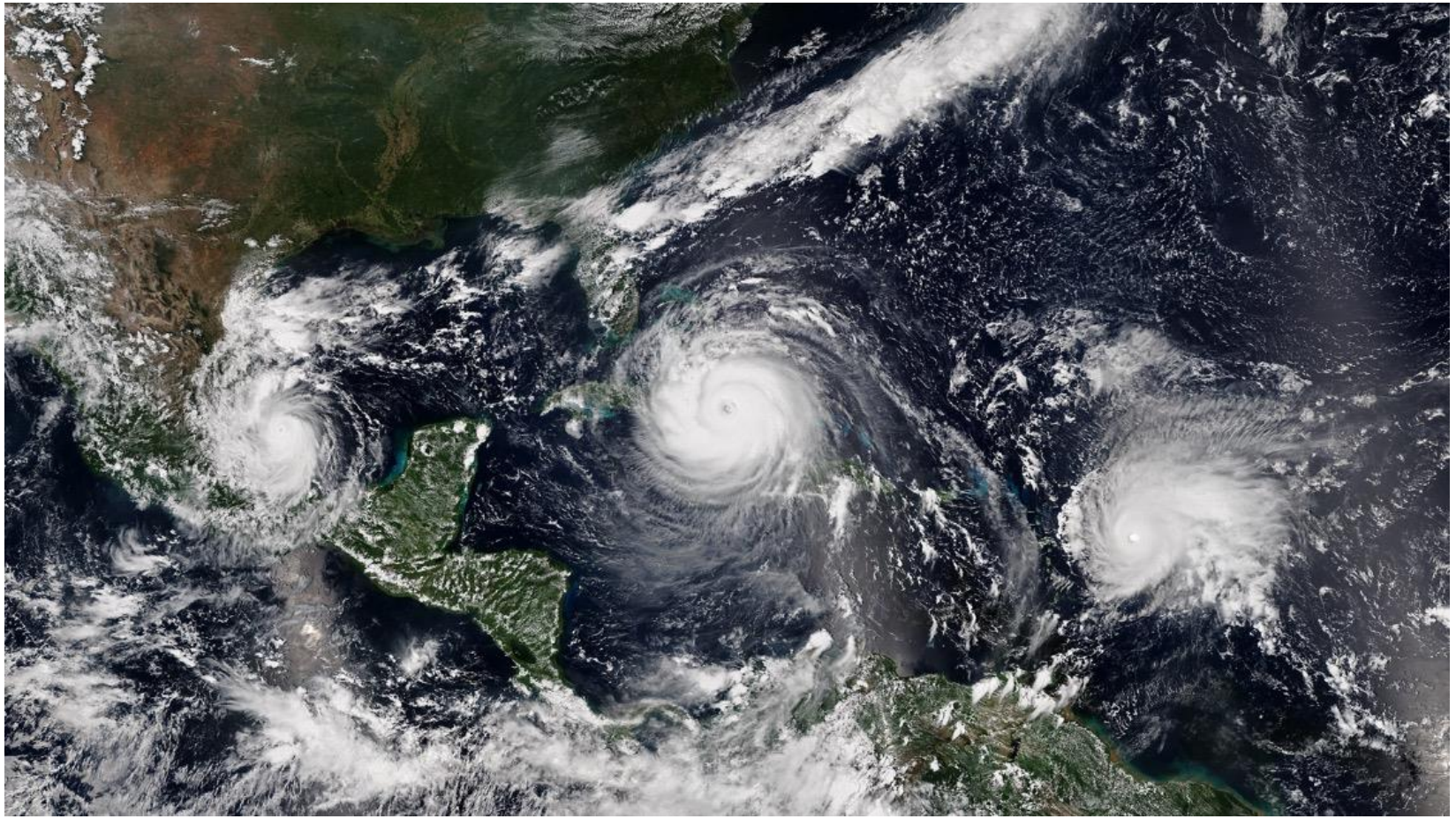
Baldwin et al. (2019) *GRL*

Cluster of tropical cyclones

Katia, Irma, Jose in 2017



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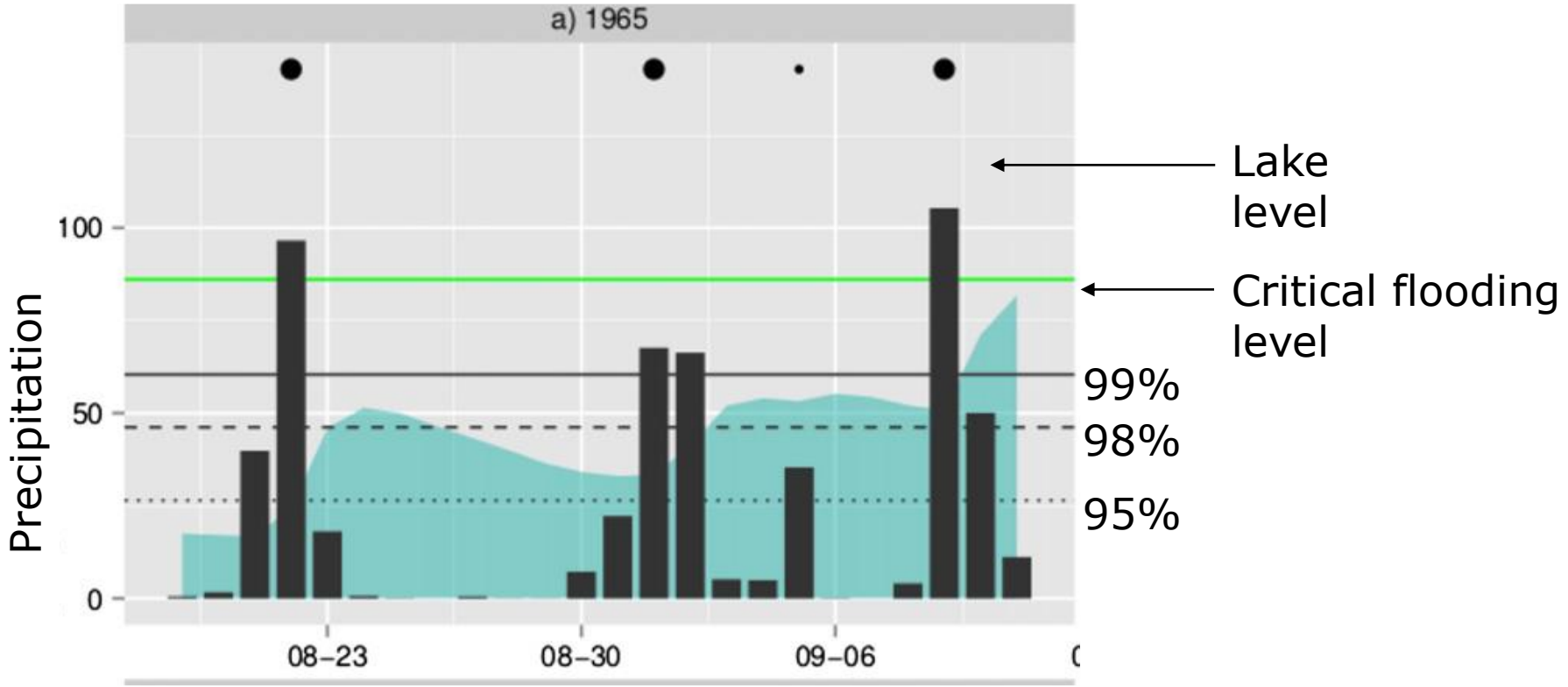
https://en.wikipedia.org/wiki/2017_Atlantic_hurricane_season#/media/File:Katia,_Irma,_Jose_2017-09-08_1745Z–1935Z.jpg

Precipitation clustering and lake flooding



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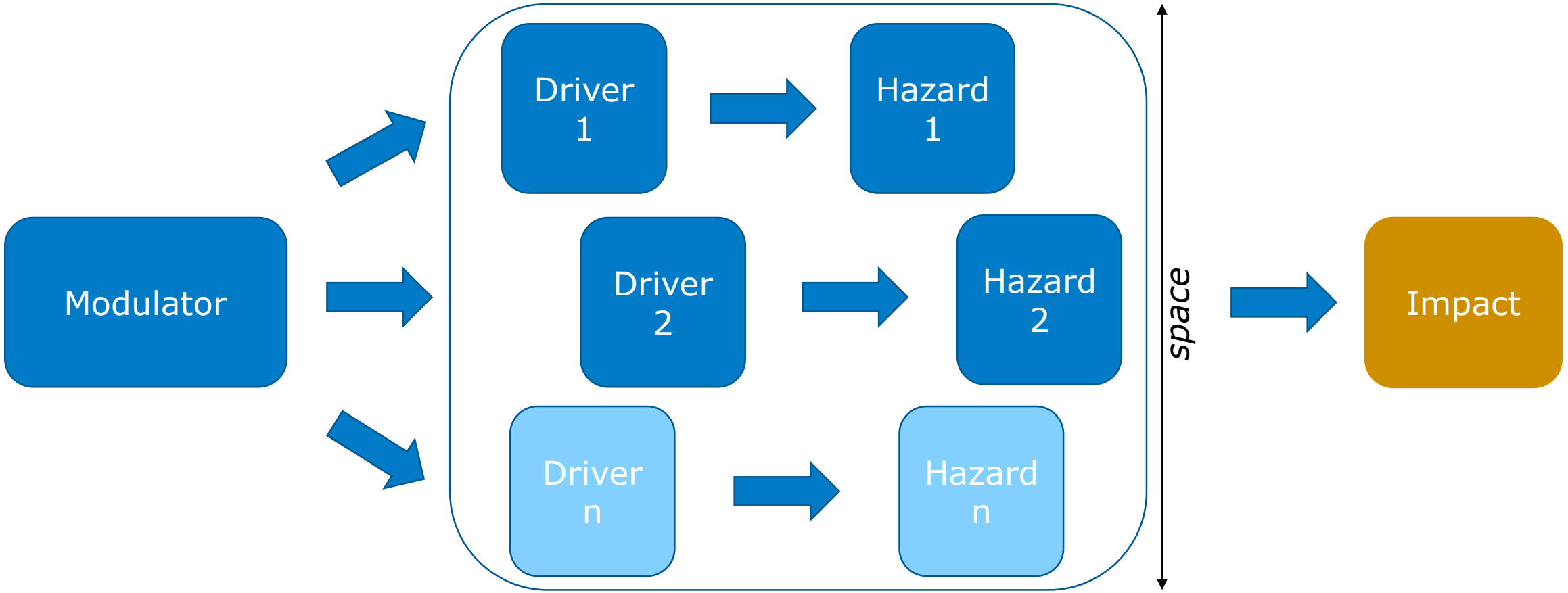
Barton et al. (2016) *MWR*

4. Spatially compounding



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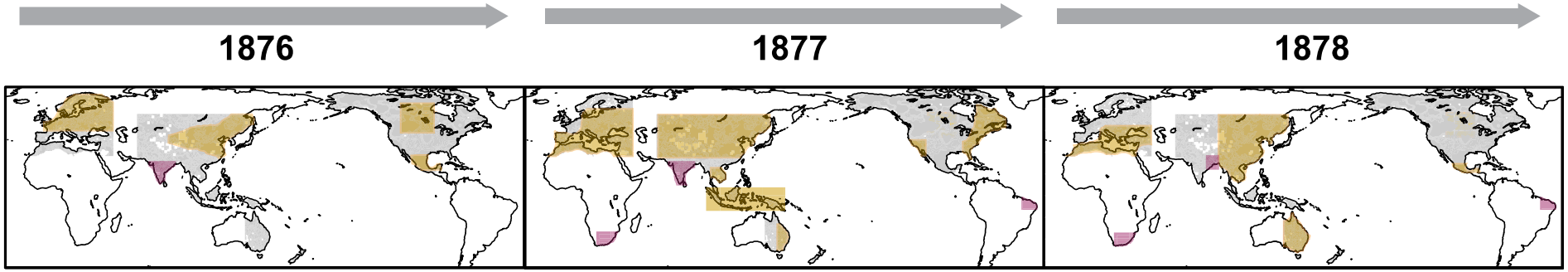
Global Famine 1876-78

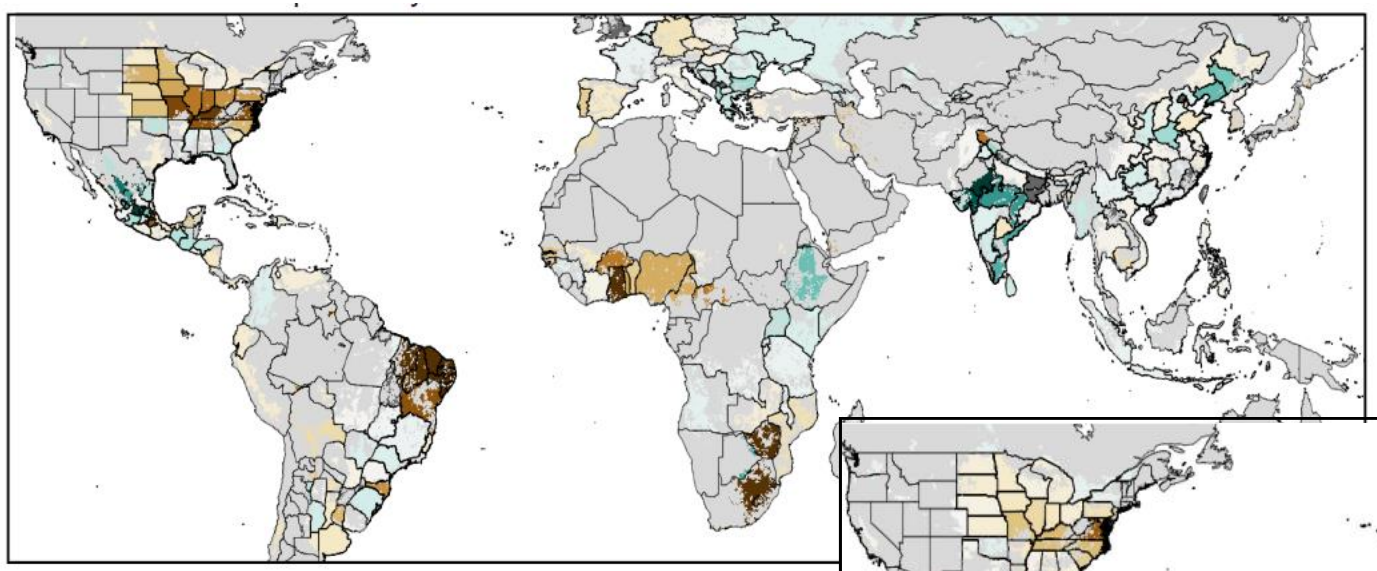


1876	1877	1878
Peninsular India, Northeastern China, Mexico, and Europe	India, China, Central Asia, Southeast Asia, Eastern Coastal Australia,California, Brazil Nordeste, eastern South Africa, and the Mediterranean Region	Northeastern India, China, Southeast Asia, Eastern Australia, Mexico, Brazil Nordeste, and the Mediterranean Region

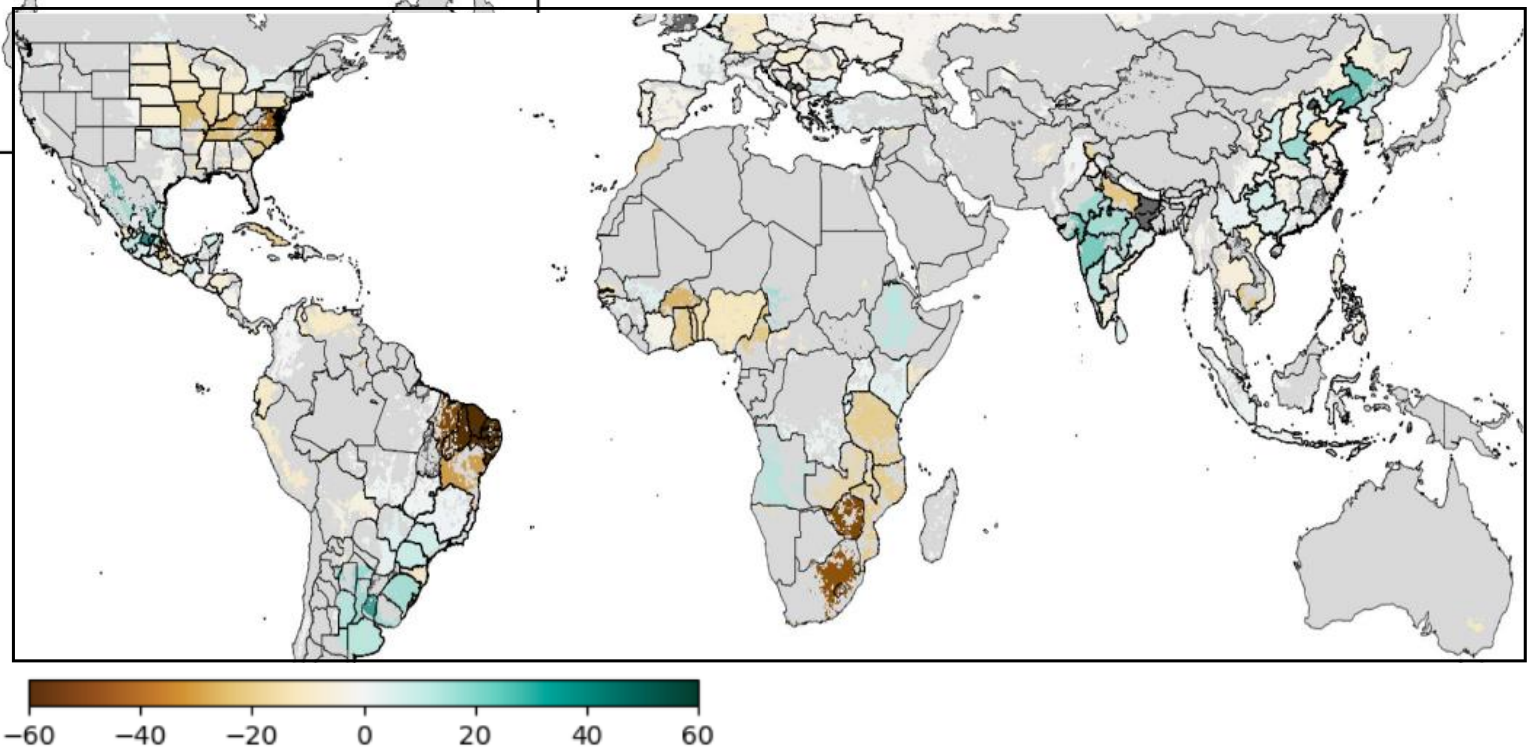
Estimated fatalities: > 50.000.000

Singh et al. (2018) *J. Clim.*

Concurrent impacts of El Niño on crop yields



Observed 1983
crop anomalies

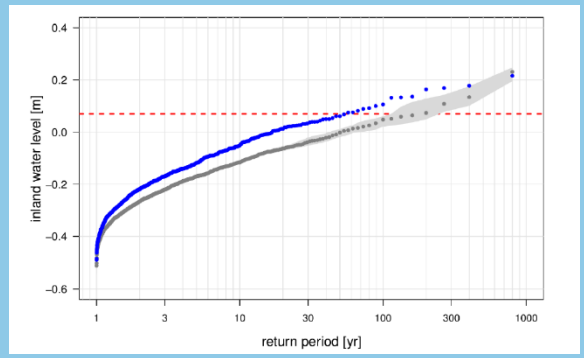


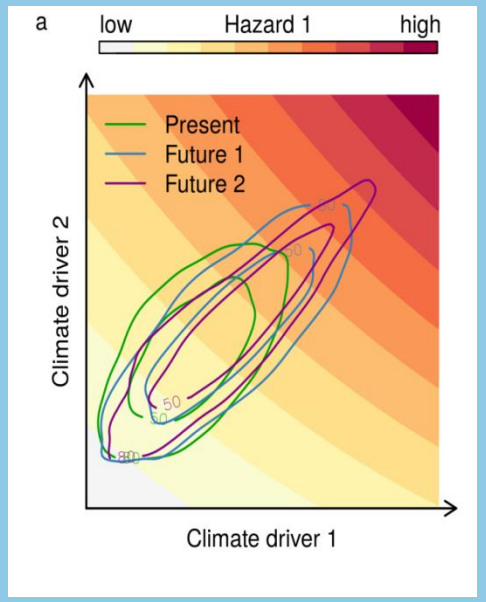
ENSO related 1983
crop anomalies

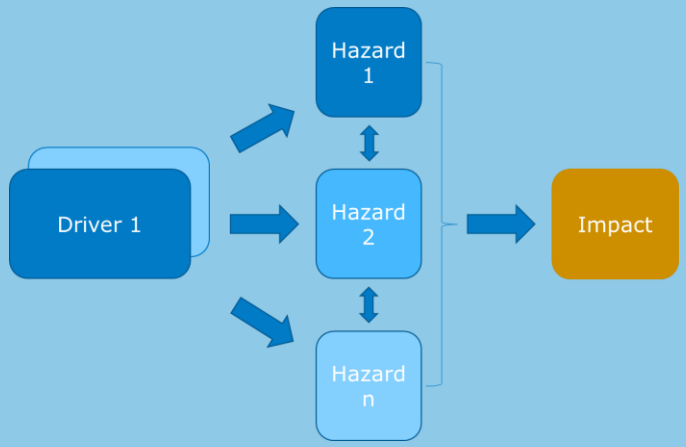
Anderson et al. (2019) *Sci. Adv.*

Conclusions

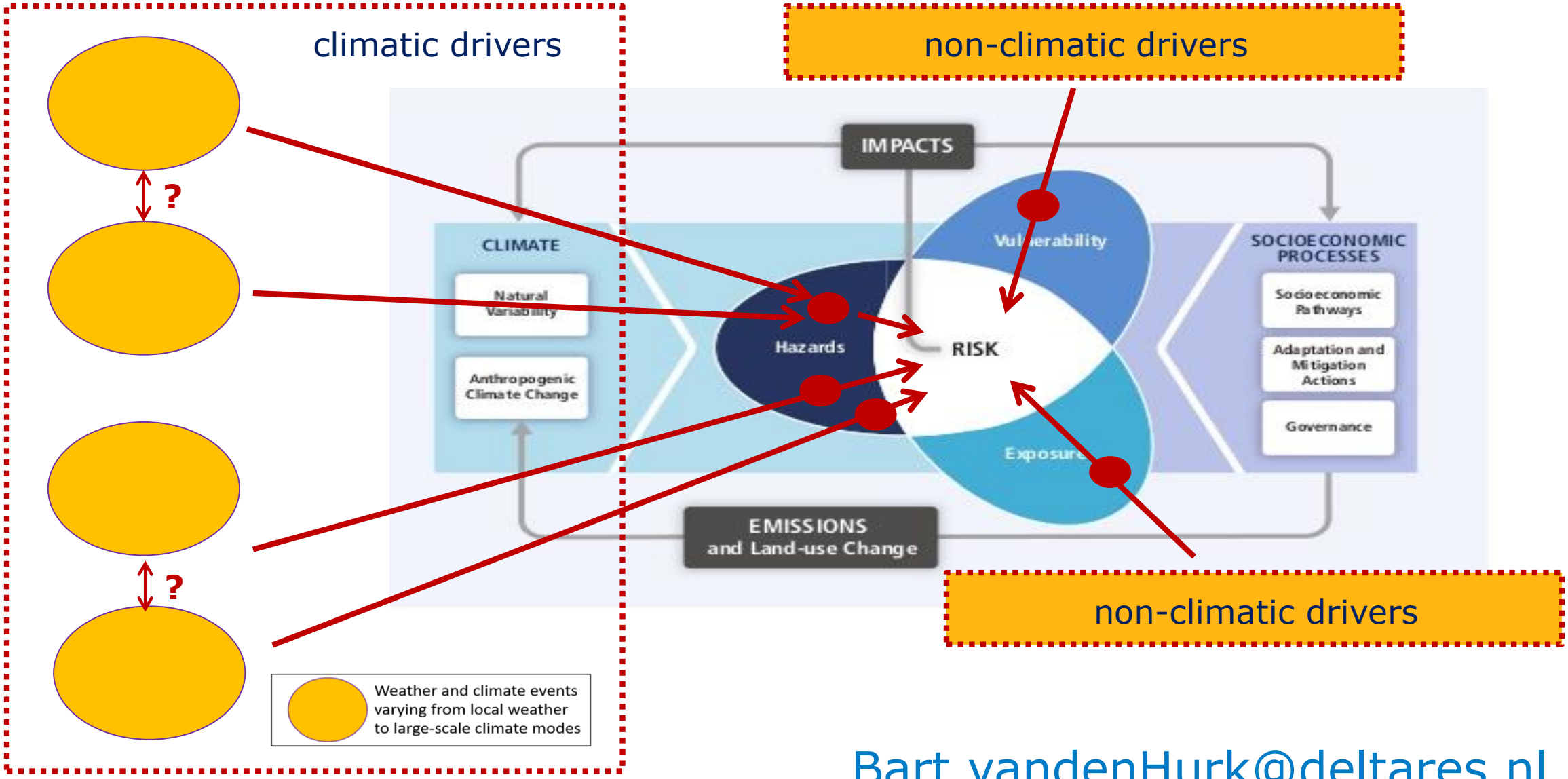
- Many events have compounding drivers
- Impacts are important starting point for compound event definition
- Typology of compound events exist, each requiring a specific analysis method







Thank you



Bart.vandenHurk@deltares.nl