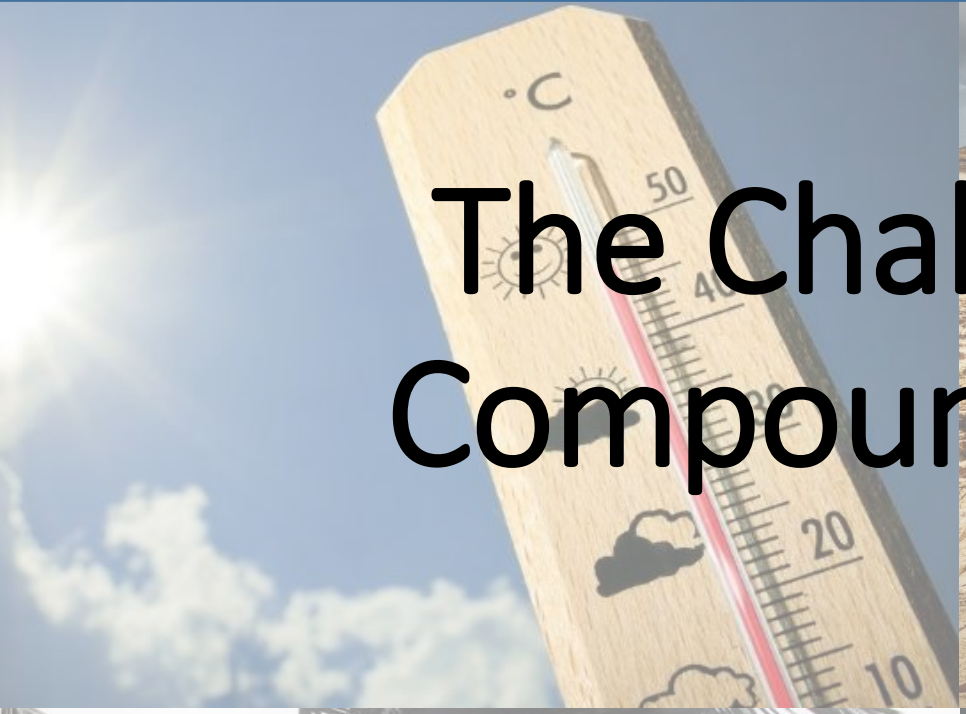


The Challenge of Compound Events

Jakob Zscheischler,

Seth Westra, Bart van den Hurk, AmirAghaKouchak, David Bresch, Michael Leonard, Andy Pitman, Sonia Seneviratne, Thomas Wahl, Philip Ward, Xuebin Zhang *et al.*

Institute for Atmospheric and Climate Science

ETH zürich

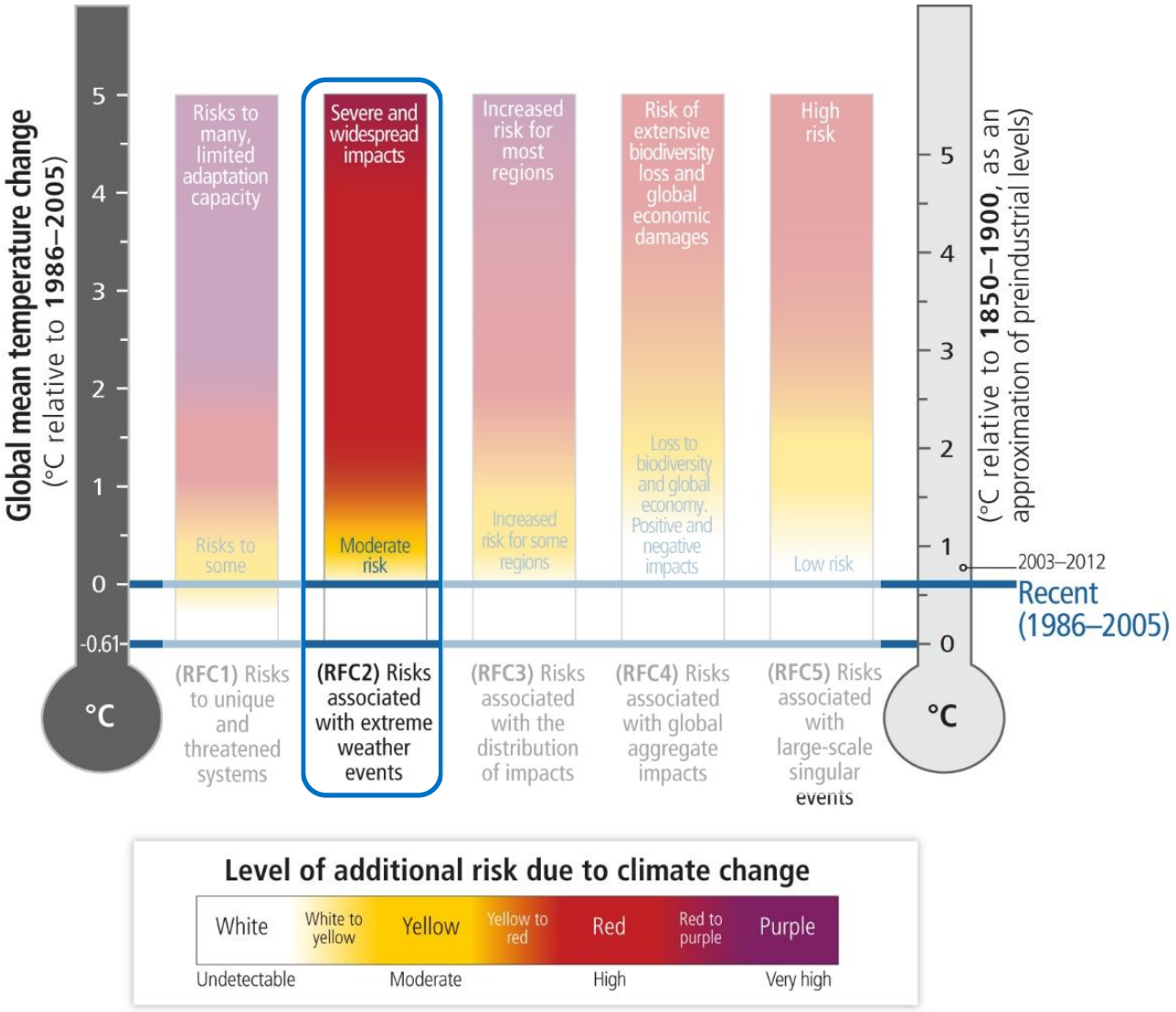
Source: inquisitr.com


Source: Getty Images


Storm Hayan


Source: climatecentral.org

Climate extremes and their impacts are one of the key risks of climate change



IPCC, 2014, *AR5*

Projections of climate extremes are based on univariate statistics

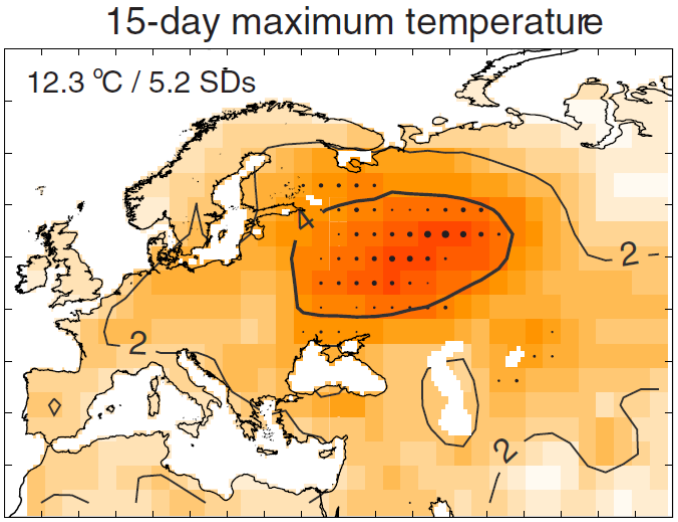
- Warmest day of the year
- Maximum daily precipitation
- Maximum length of dry spell
- Frequency of heat waves
- Intensity of droughts
- …

IPCC, 2014, *AR5*

Extreme event in Russia 2010

Climate

- Record breaking temperatures
- Low precipitation
- Very dry soils

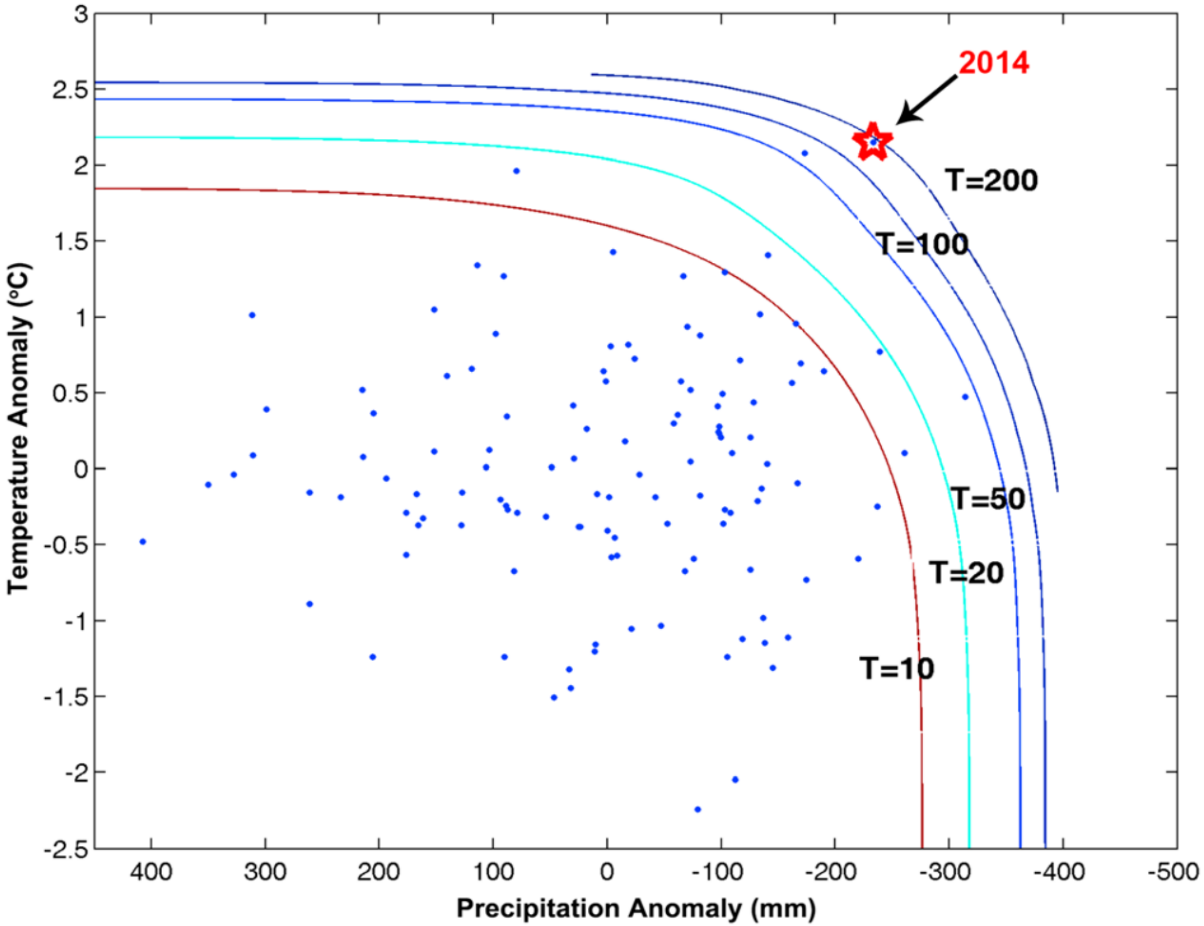


Impacts

- Wildfires
- Crop damage
- Air pollution
- Human mortality
- Record-breaking decrease in carbon uptake

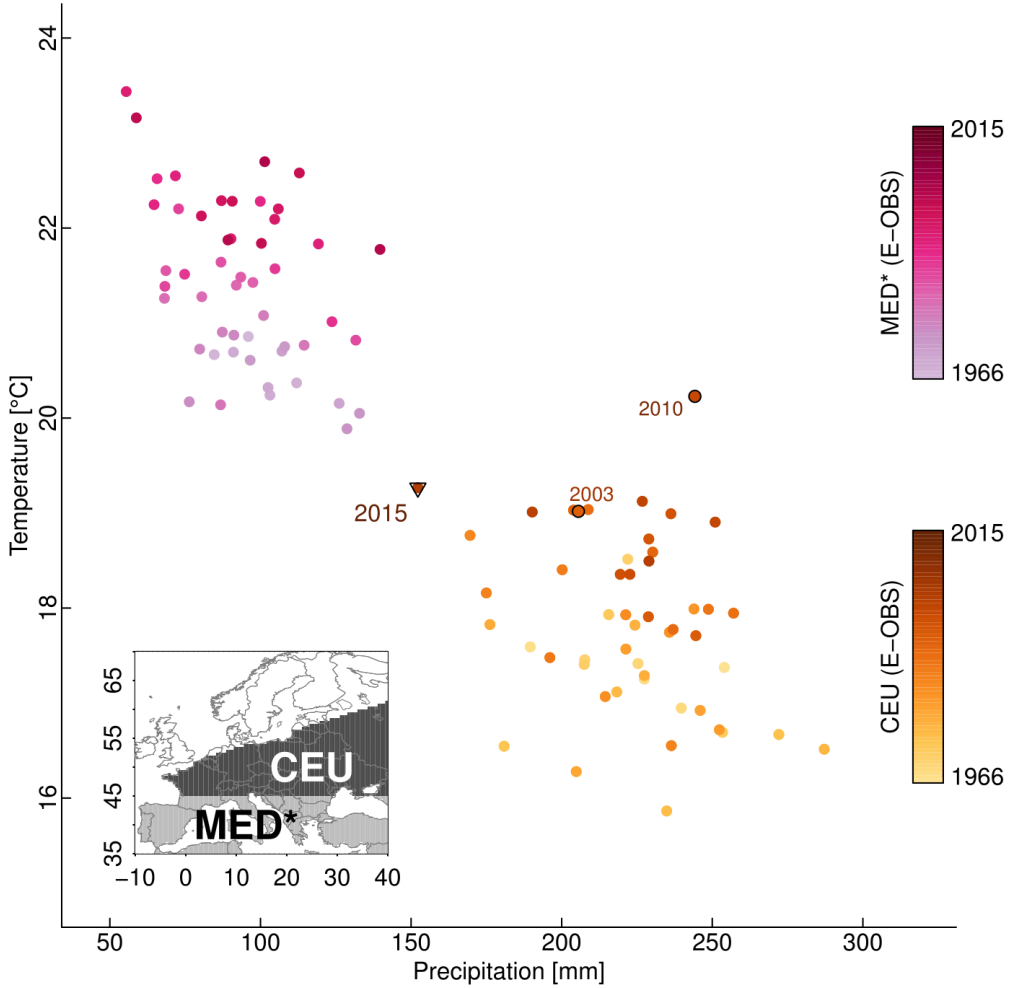
Barriopedro et al, 2011; Grumm 2011; Konovalov et al., 2011; Hauser et al, 2016; Zscheischler et al., 2014

California 2014



AghaKouchak et al., 2014

The summer of 2015 in Central Europe



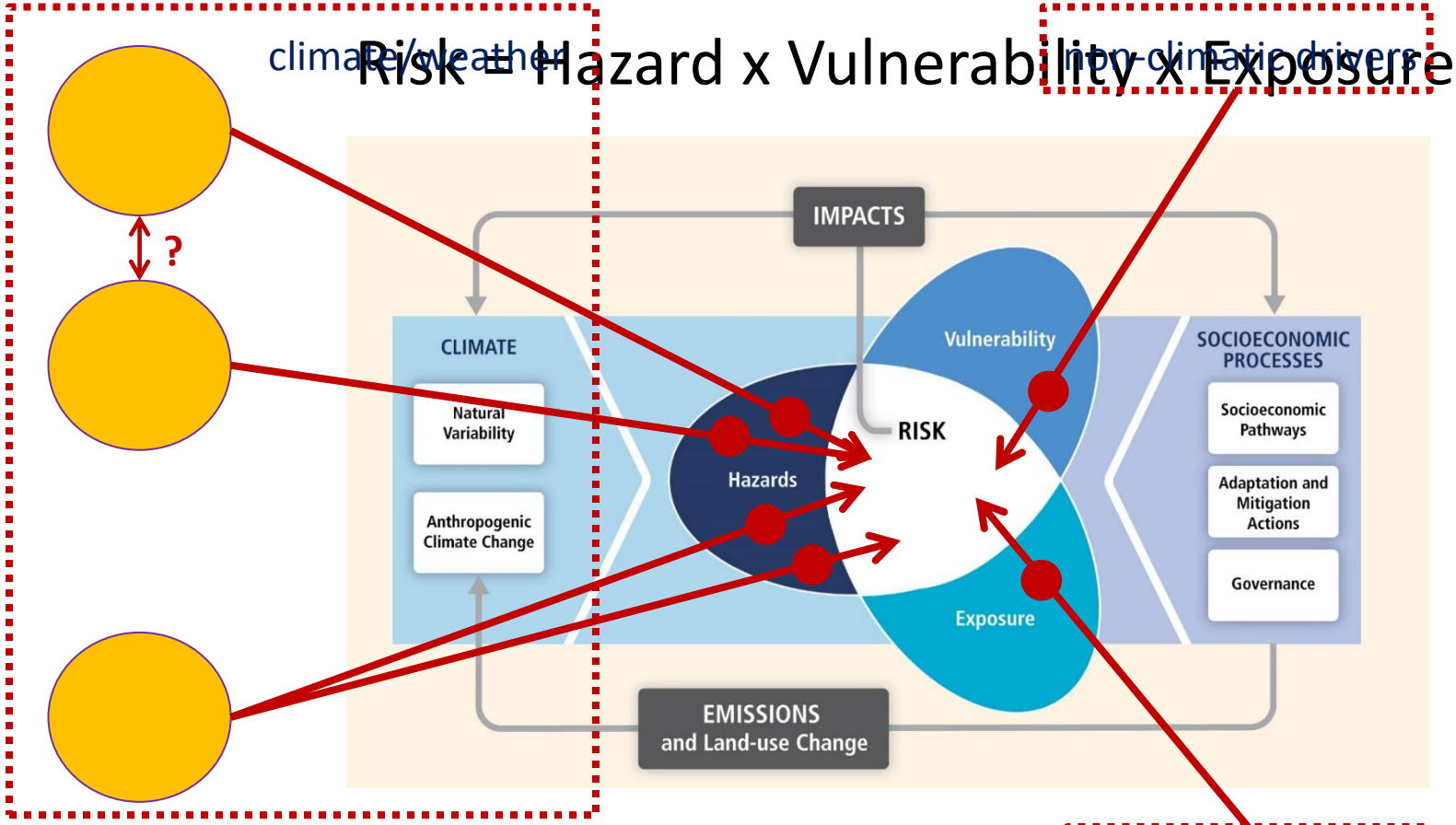
Orth, Zscheischler & Seneviratne, 2016

Challenge

How predictable are events such as Russia 2010, California 2014, Central Europe 2015?

Risk

Risk = Hazard x Vulnerability x Exposure



A new definition

Compound weather/climate events refer to **multiple drivers** that combine to affect **hazards** contributing to societal or environmental **risk**.

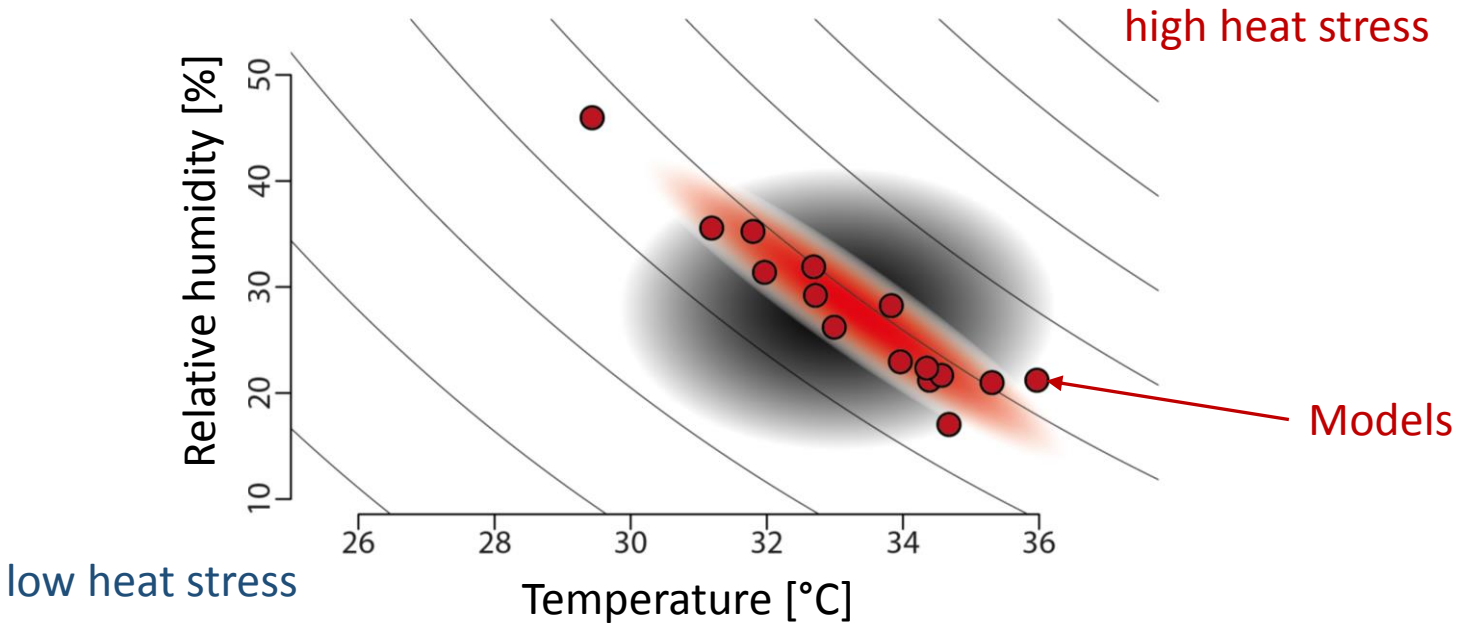
The challenge of dependence

- Drivers of hazards may be dependent
  - Needs to be incorporated in risk assessments
  - Many hazard indicators incorporate dependence implicitly

- Examples
  - Drought (precipitation, temperature)
  - Fire risk (temperature, relative humidity)
  - Heat stress (temperature, relative humidity)

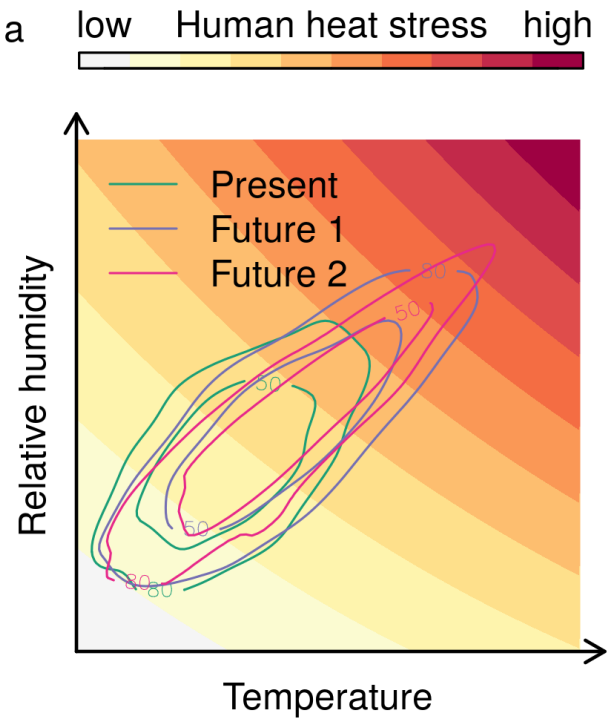
Dependence can reduce uncertainty

- Heat stress (temperature, relative humidity)



Fischer & Knutti, 2013

This may increase uncertainty for others



- Separate hazards and hazard drivers
- Understand processes that lead to dependence between hazard drivers
- The will prevent to get the “right answer for the wrong reasons”

Initial idea provided by Erich Fischer

Impact of climate change

- Affects trends in marginals
- Affects distribution of marginals
- Influences dependence between variables

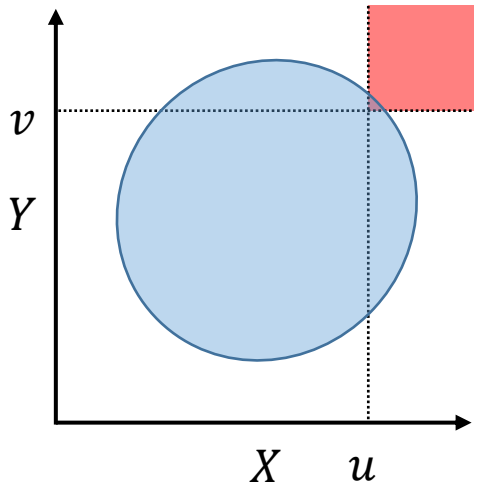
What about compound hazards?

- Drought & heat
  - impacts ecosystems
- Storm surge & rainfall extremes
  - cause coastal floods
- Storm surge & river discharge extremes
  - cause coastal floods
- Discharge extremes at river confluences
  - cause floods
- Precipitation & wind extremes
  - damage infrastructure

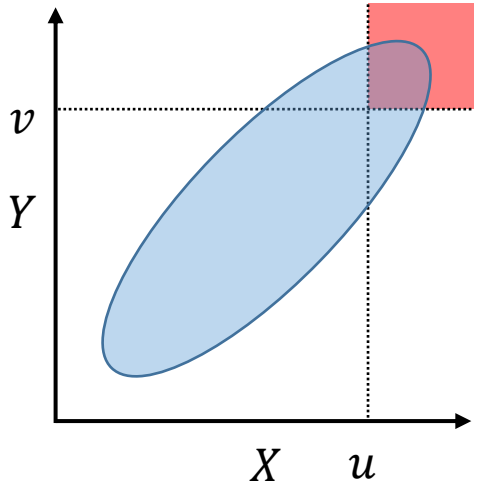
Zscheischler et al., 2014; Van den Hurk et al., 2015; Wahl et al., 2015; Bender et al., 2016; Martius et al., 2016

Dependence affects compound hazards

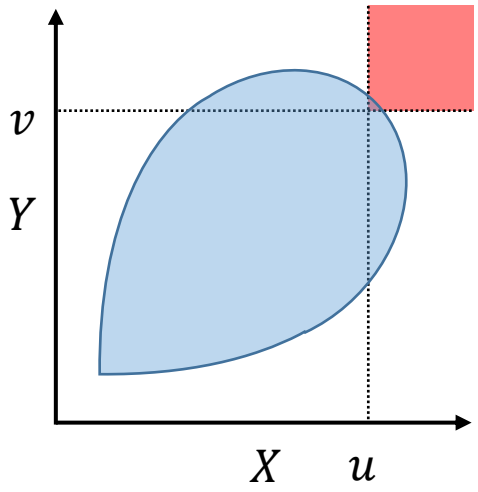
X and *Y* independent

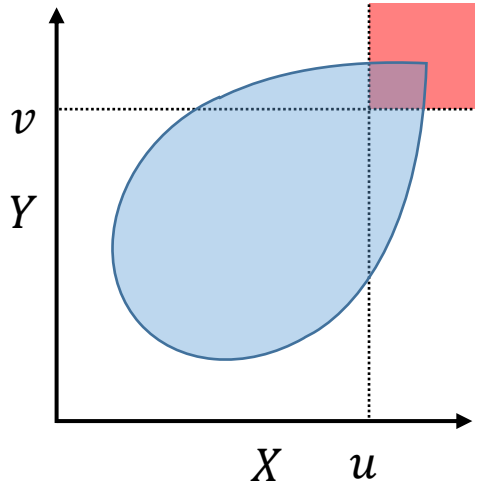


X and *Y* dependent



Dependence can vary across percentiles

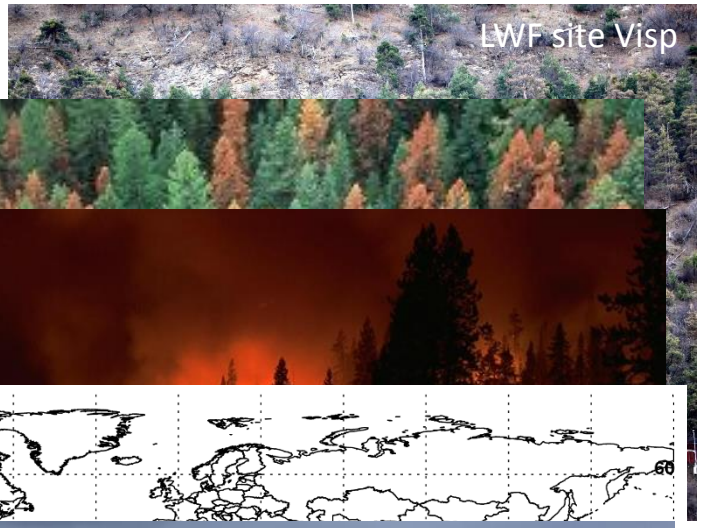




Example: hot & dry

Many impacts are associated with extremely hot and dry conditions:

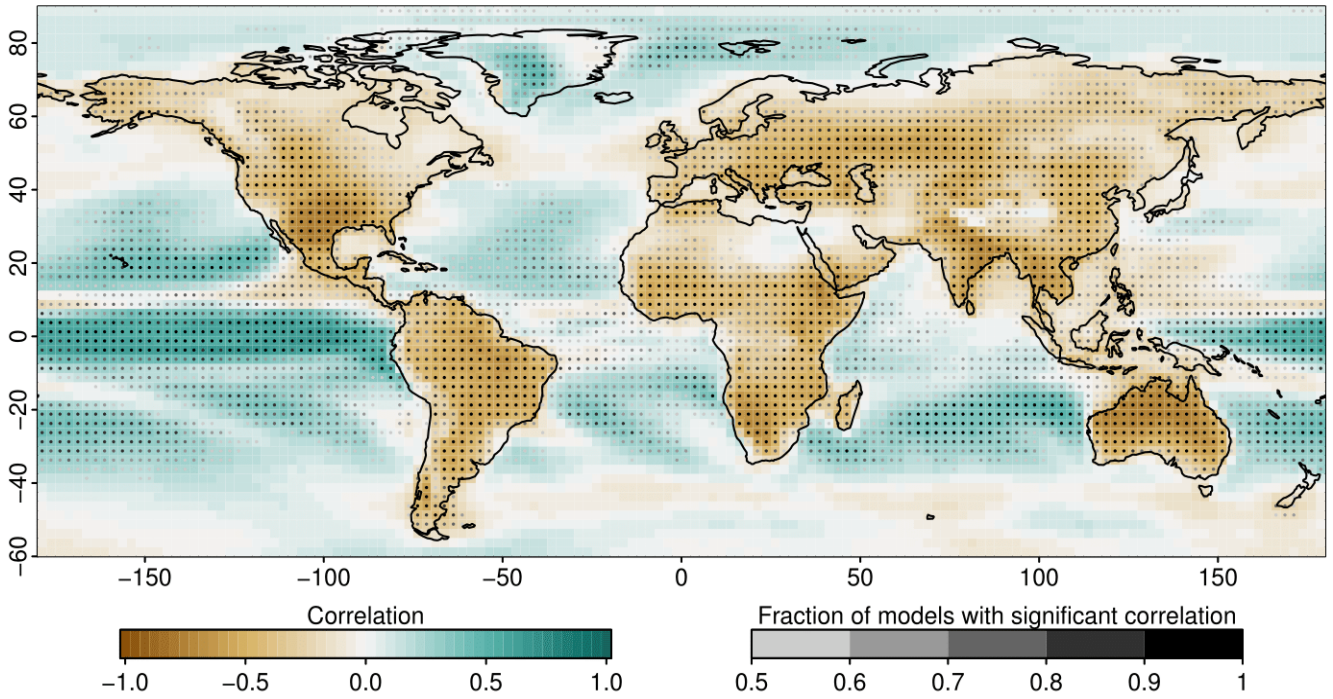
- tree mortality
- insect outbreaks
- fires
- spread of diseases
- crop failure
- …



Allen et al., 2010; Anyamba et al., 2014; Bandyopadhyay et al., 2012; Brando et al., 2014; Chretien et al., 2007; Padmanabha et al., 2012; Williams et al., 2010; Witte et al., 2011

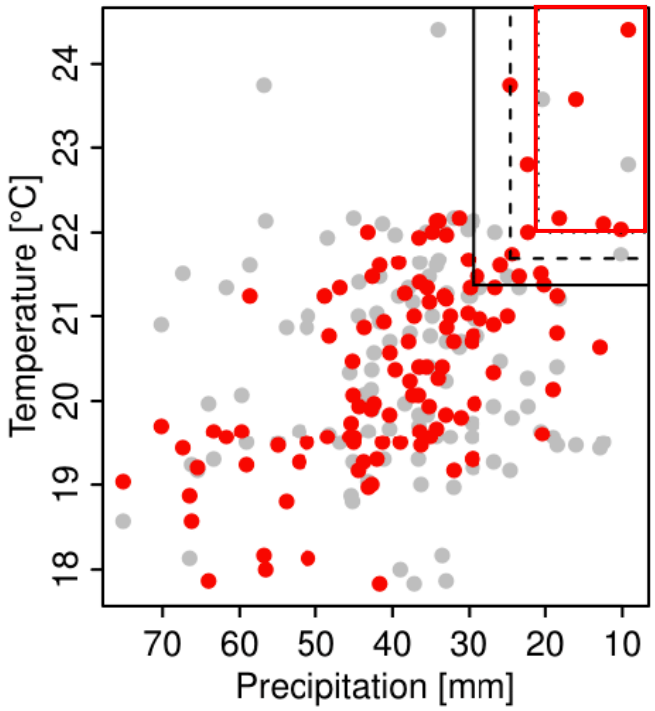
Correlation between summer T and P

Climate models (CMIP5)



Madden & Williams, 1978; Trenberth & Shea, 2005; Zscheischler & Seneviratne, 2017

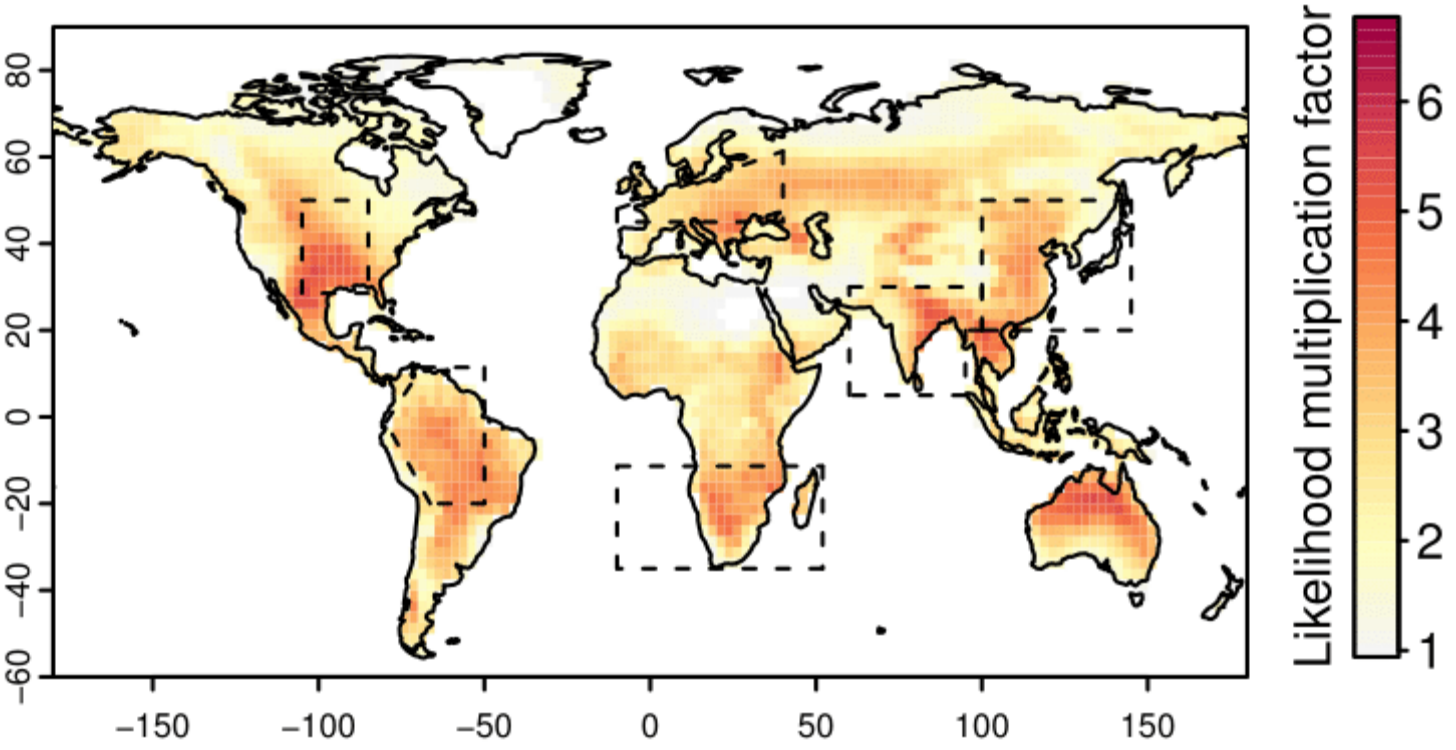
One location in Western Russia



1901–2013, r=0.63
T randomly permuted
78th percentiles: p = 0.05, RP = 20 yr (independent); p ≈ 0.13, RP ≈ 8 yr (correlated)
86th percentiles: p = 0.02, RP = 50 yr (independent); p ≈ 0.08, RP ≈ 13 yr (correlated)
90th percentiles: p = 0.01, RP = 100 yr (independent); p ≈ 0.05, RP ≈ 18 yr (correlated)

Likelihood of hot and dry summers

Average over 83 climate model runs.



Zscheischler & Seneviratne, 2017

Correlation between summer T and P

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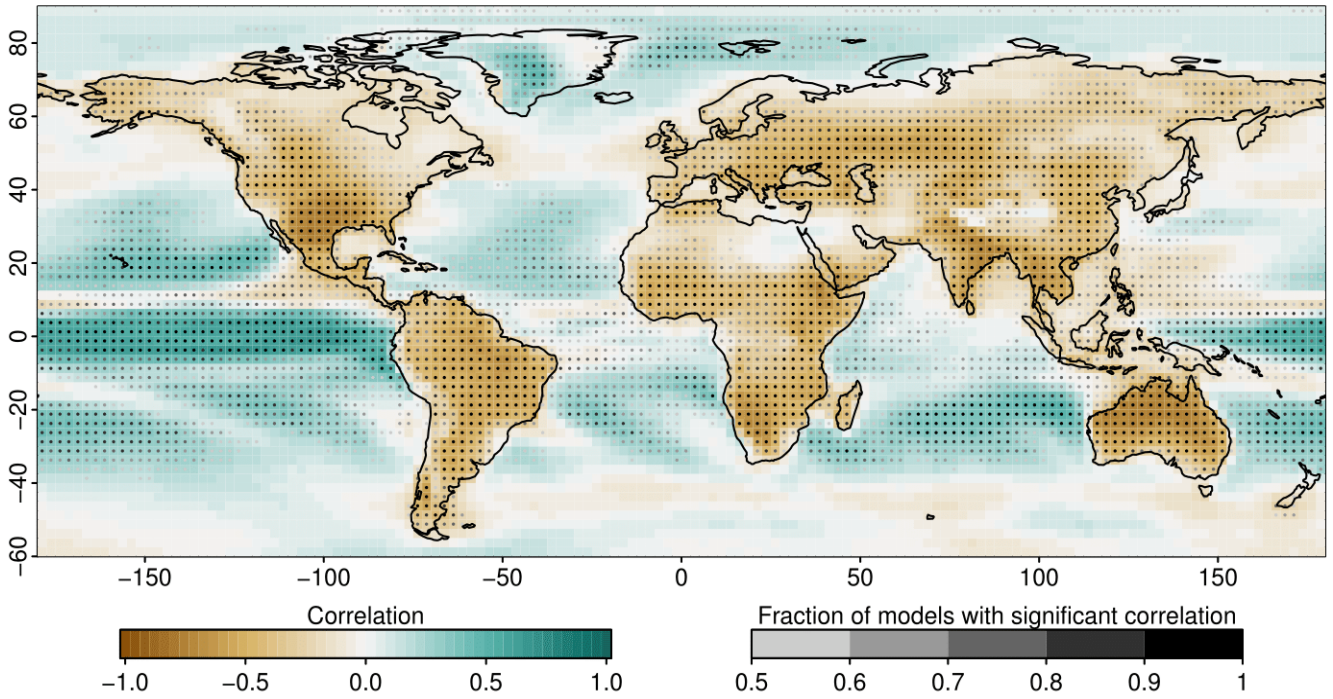
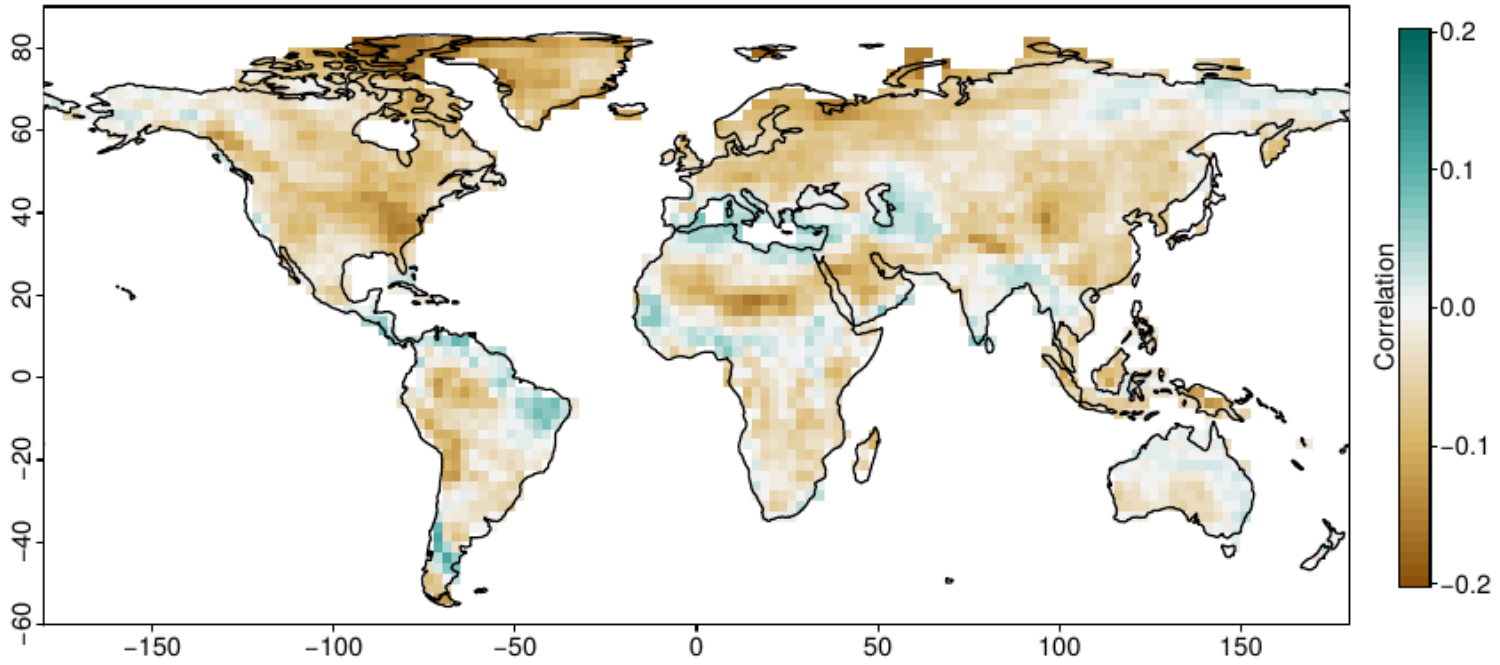


Madden & Williams, 1978; Trenberth & Shea, 2005; Zscheischler & Seneviratne, 2017

Negative correlation intensifies in future

(2001-2100) – (1870-1969)

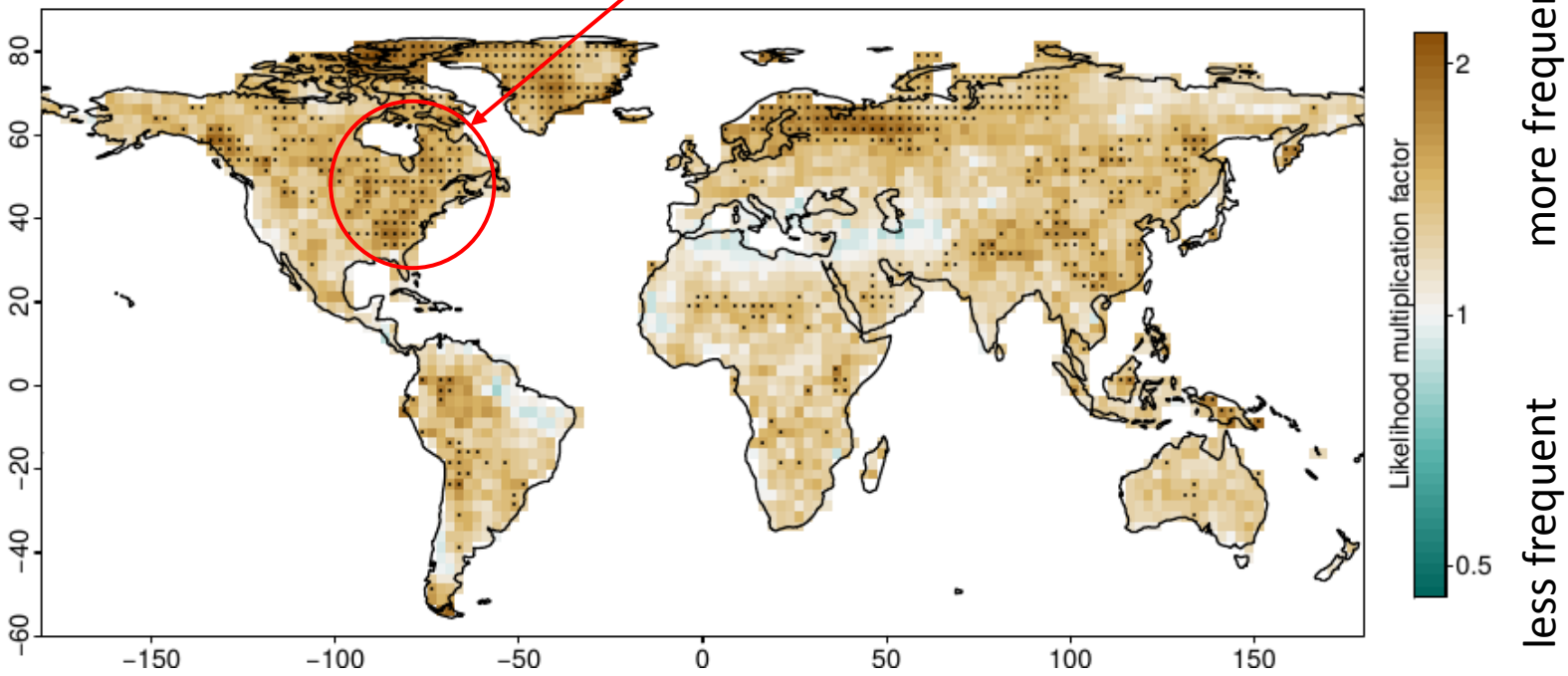


Zscheischler & Seneviratne, 2017

Future changes in hot and dry summers

Change in 100-year events

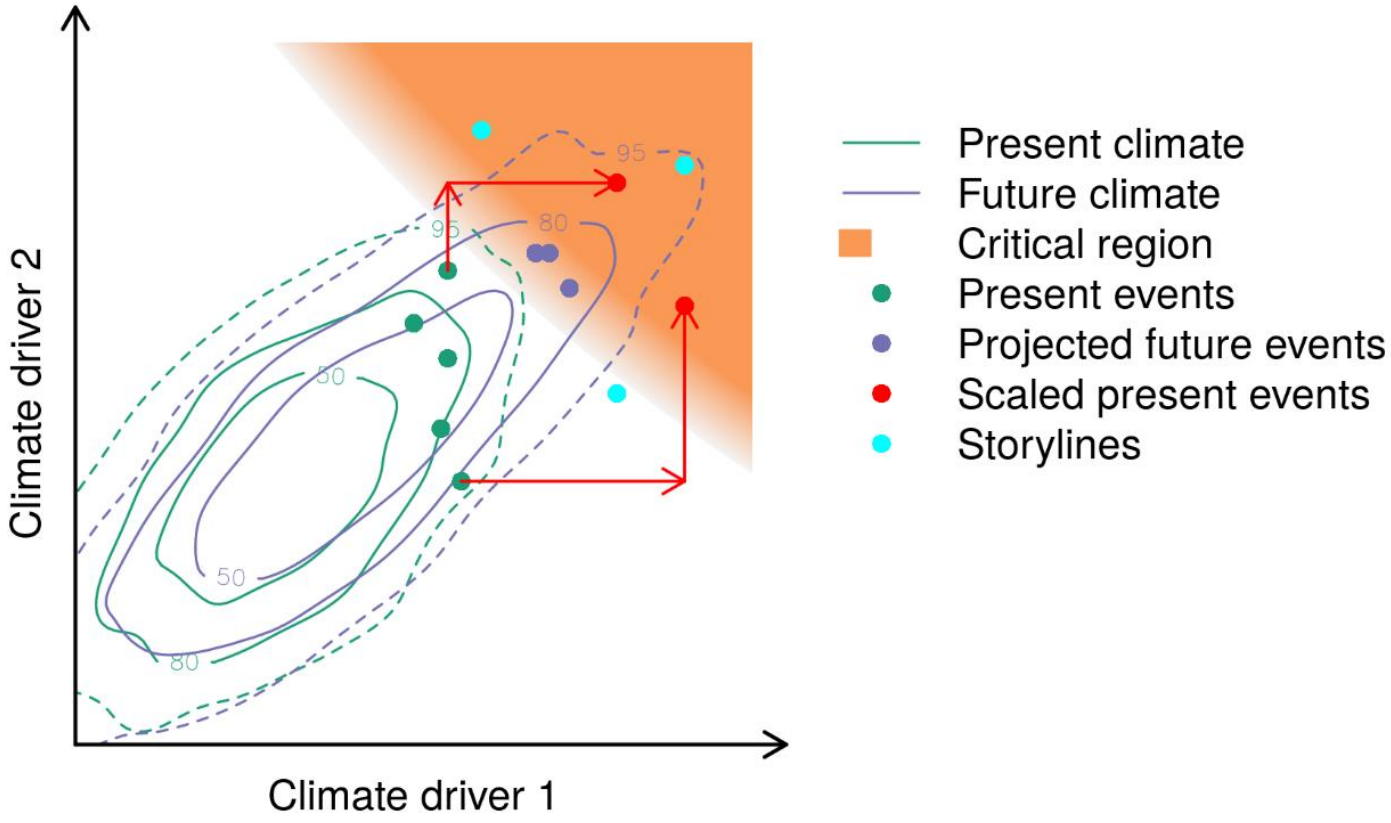
A 100-year summer in the past will be a 50-year summer in the future



Strong greenhouse-gas forcing scenario (RCP8.5), (2001-2100) vs. (1870-1969).

Zscheischler & Seneviratne, 2017

Ways to obtain possible future events



Conclusions and ways forward

- Most climate-related catastrophes are caused by compound effects of multiple drivers
- We lack theoretical frameworks for frequency analysis, risk assessment, and attribution of compound events
- “Bottom-up” approaches help identifying the unique combinations of climate drivers that affect risk
- To resolve compound events, high-resolution climate modelling and improved downscaling is needed
- Research on compound events require strong collaboration across multiple fields of research

Thank you!

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ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE
VU VRIJE UNIVERSITEIT AMSTERDAM
WCRP World Climate Research Programme