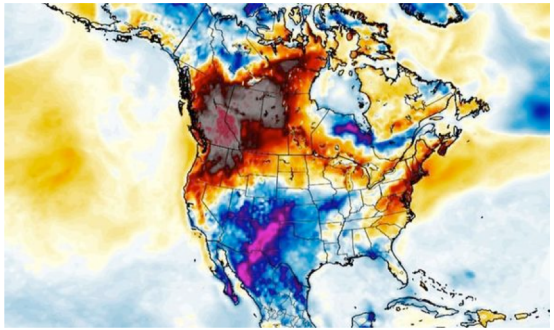
Attribution of extreme events to climate change

Aglaé Jézéquel, LMD

Recent extreme weather events – part of the natural variability...



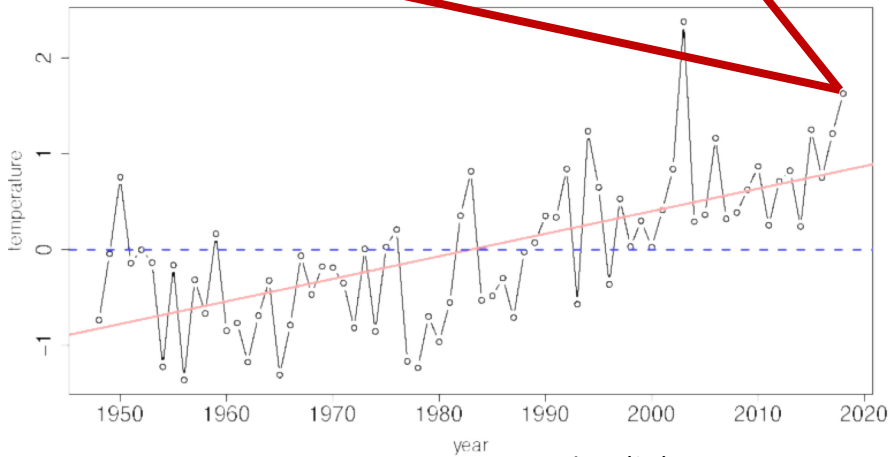
Canadian heatwave - June 2021

German flood - July 2021

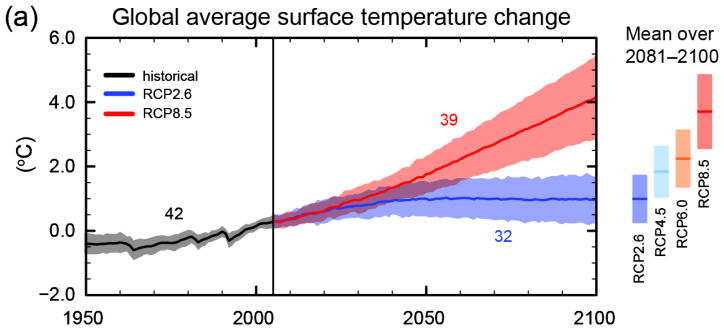
Australian bushfires – 2019-2020

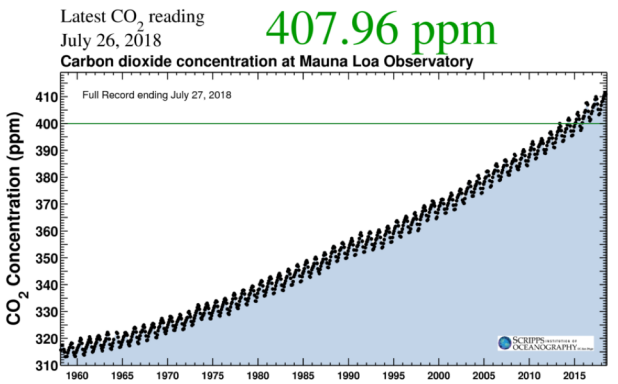
French drought - May vs July 2018

… in a changing climate

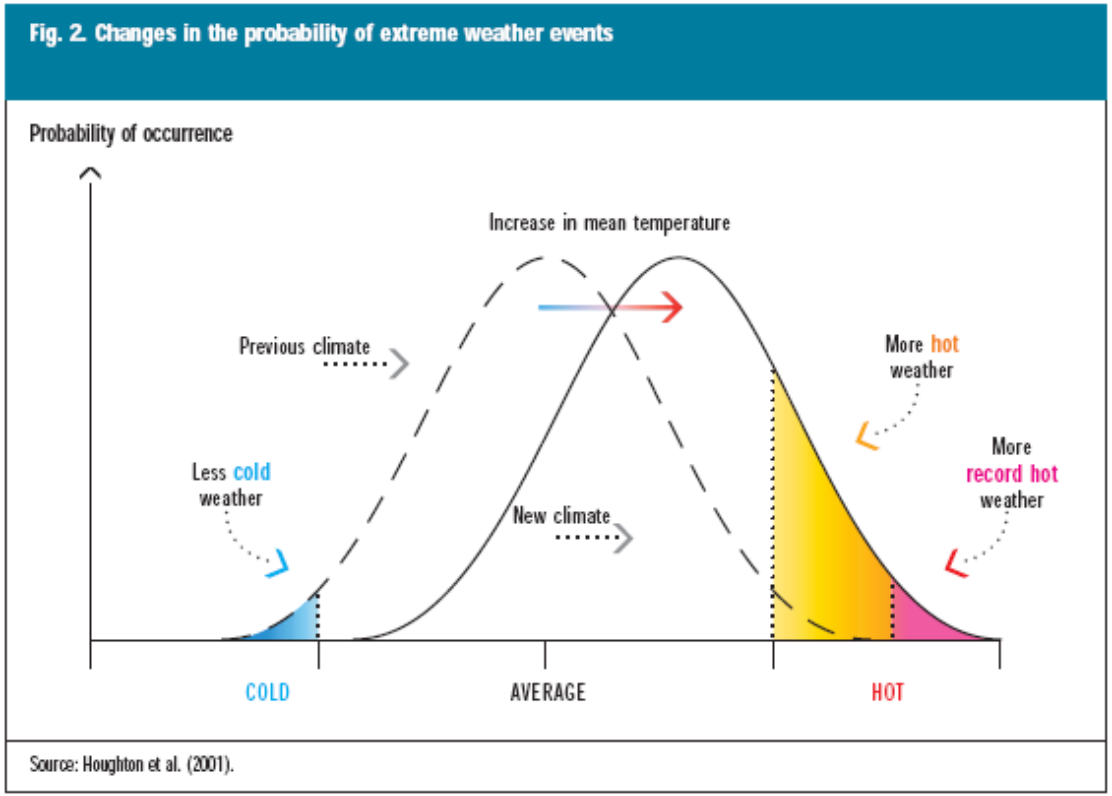


European summer anomalies (°C)

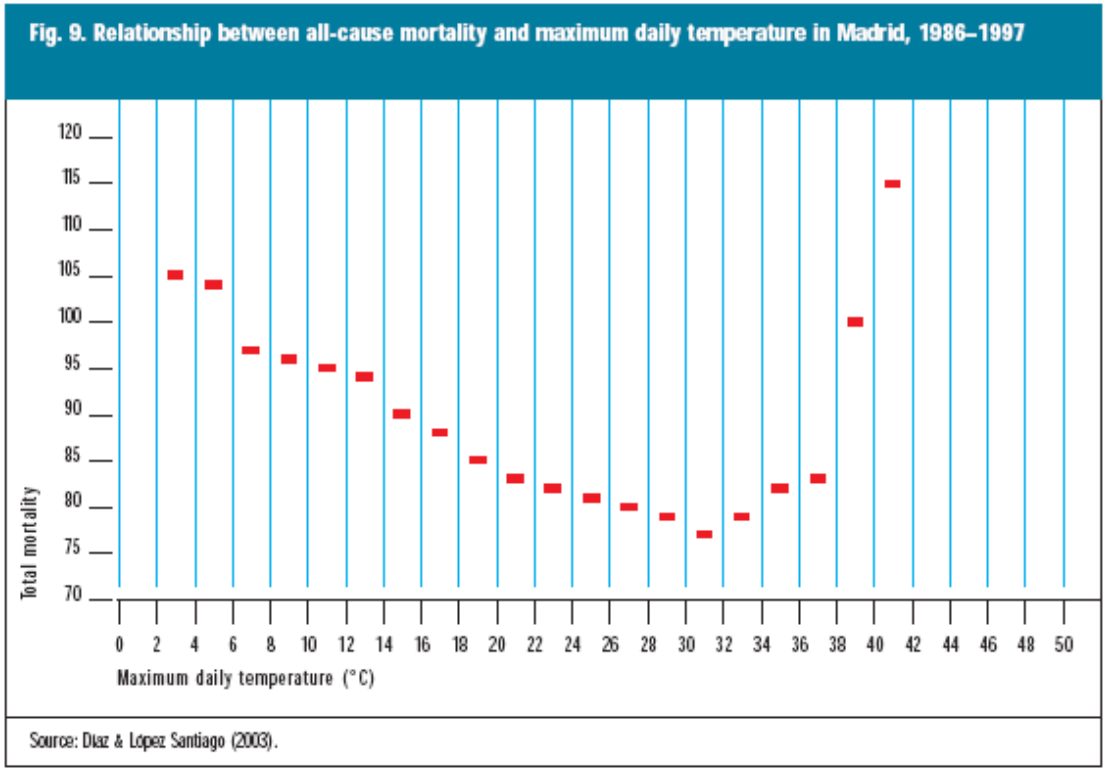




First effect of a change: small changes in mean can lead to « large » effects in extremes



A small shift in the extremes can lead to large impacts

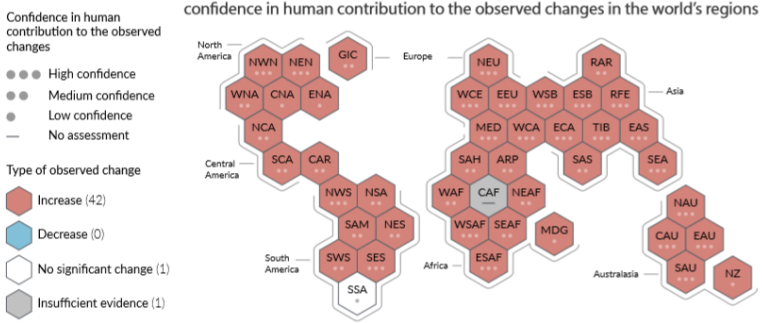


WHO, 2005

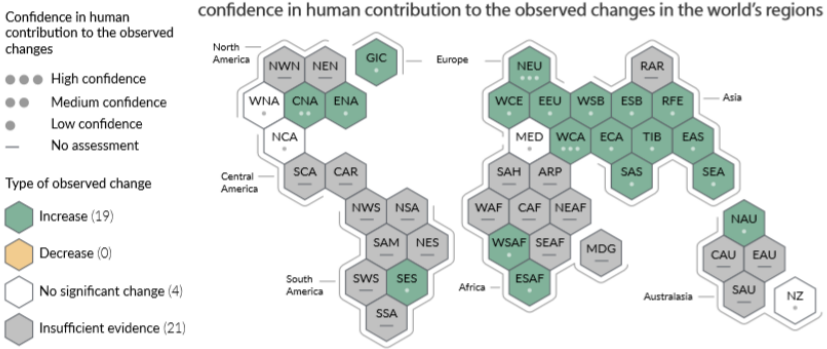
Mortality vs temperature in Madrid

Climate change is already affecting every region across the globe with human influence contributing to many observed changes in weather and climate extremes

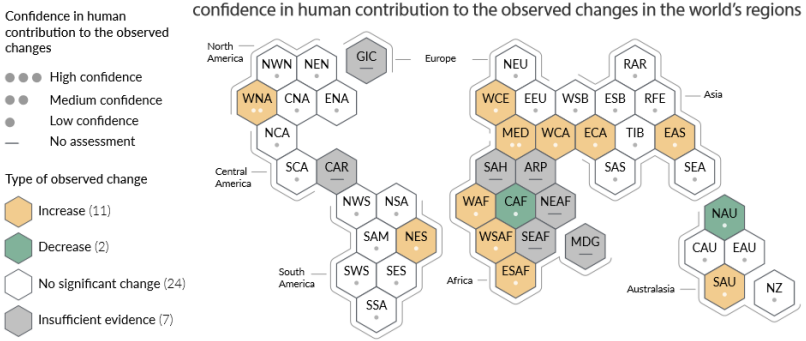
a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions



b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions

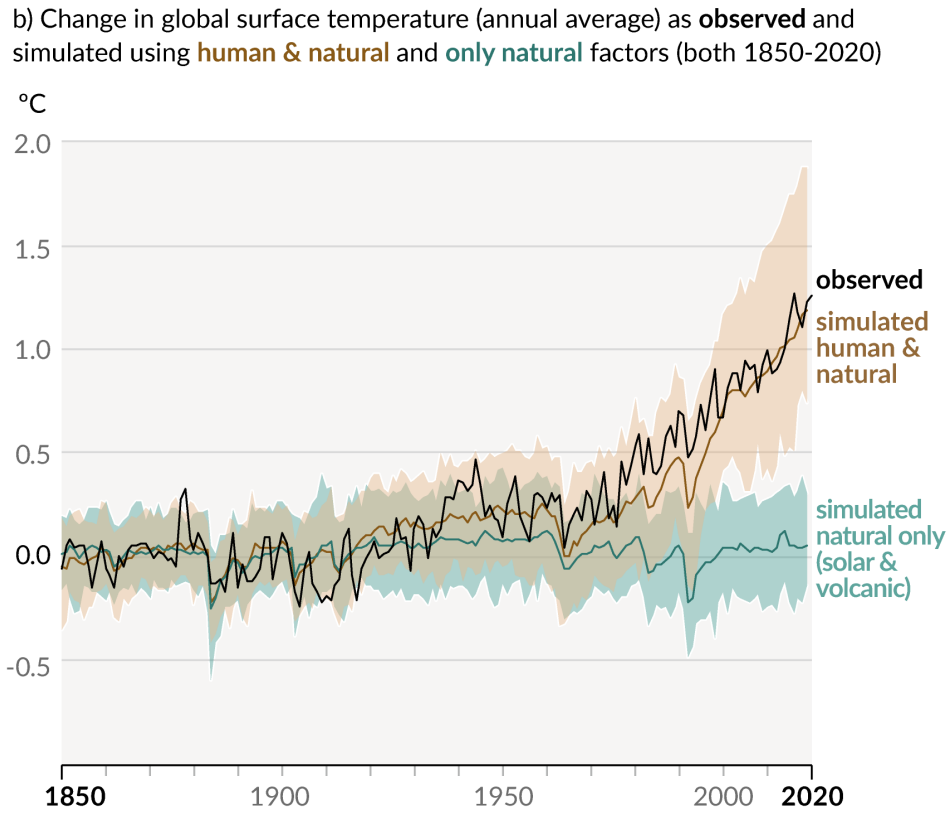


c) Synthesis of assessment of observed change in **agricultural drought** and confidence in human contribution to the observed changes in the world's regions



IPCC AR6 WGI

Global temperature change attribution

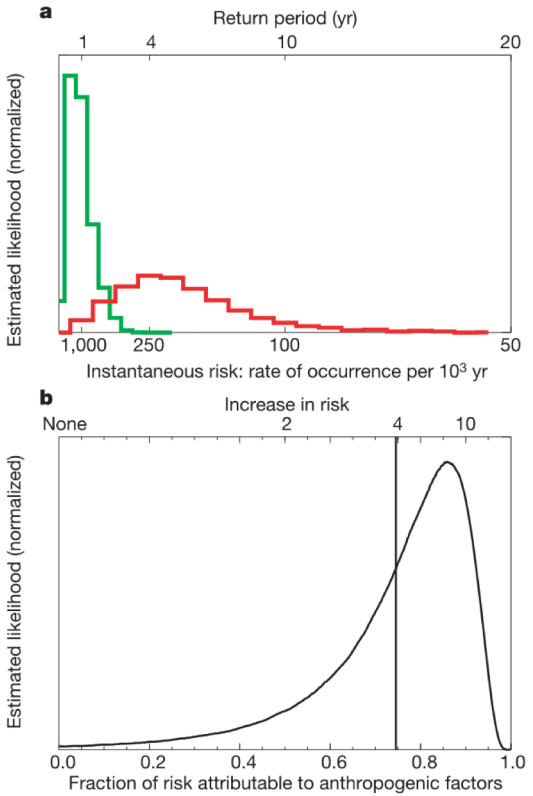


IPCC AR6 WGI

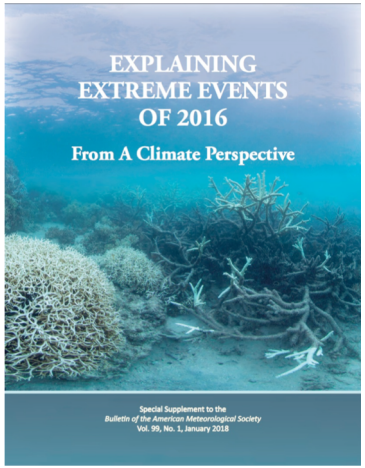
What is extreme event attribution?

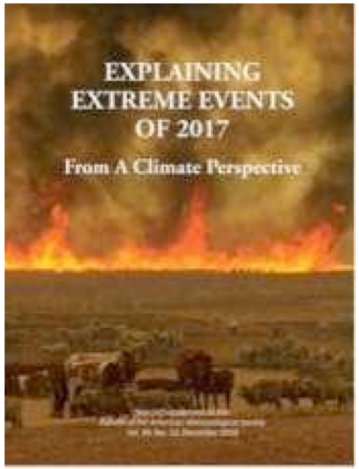
Beginnings of EEA

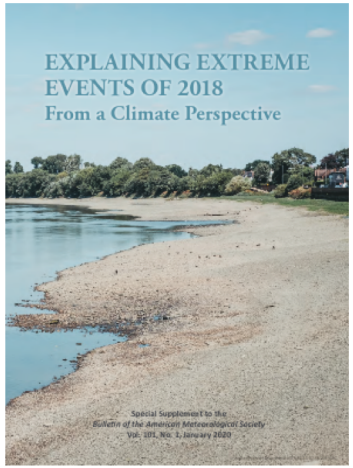
- “Will it ever be possible to sue anyone for damaging the climate?” *Allen (2003) Nature*
- First EEA of summer 2003 European heawave -> Change in risk of mean European summer temperatures exceeding the 1.6 K threshold. *Stott et al (2004)*

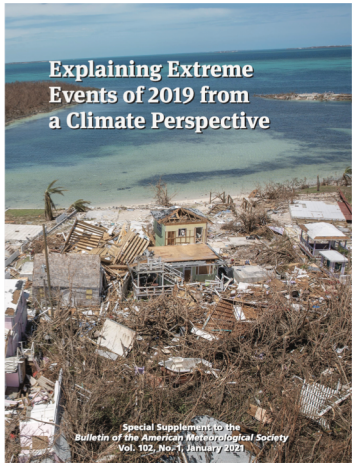


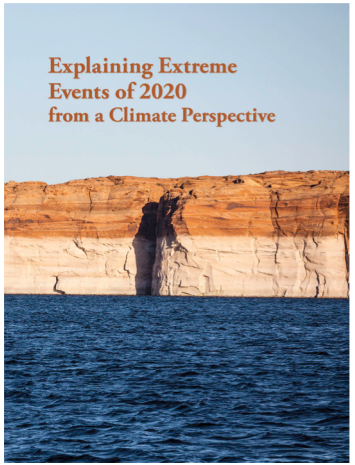
A booming field











Framing Extreme Event Attribution

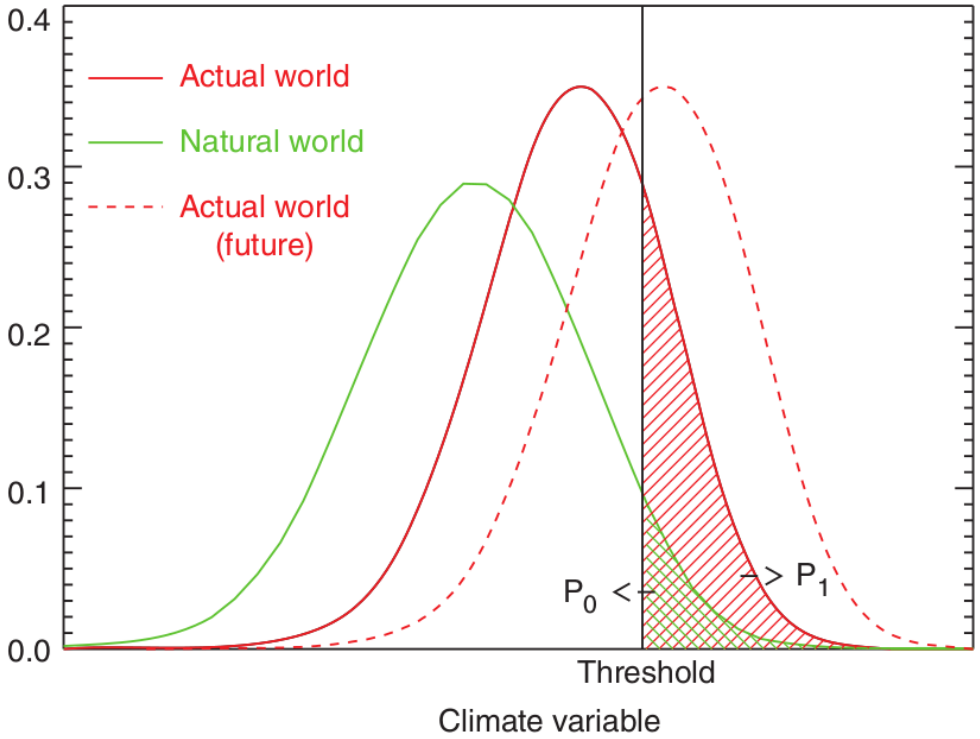
Was this event influenced by climate change ?

1) How does one define the event to study ?
Choice of the event, of the region, of the duration. Definition of the class of events.

2) What does one mean by “influenced by” ?
Choice of the level of conditioning

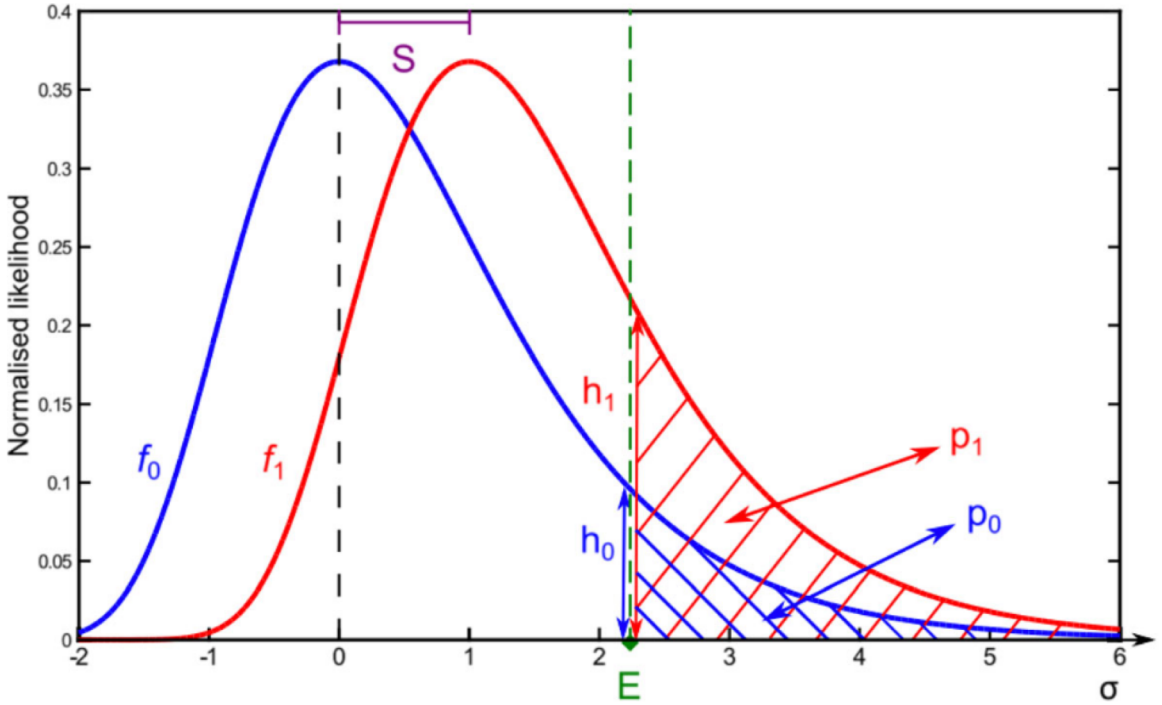
3) How does one represent climate change ?
Choice of the natural world

General approach



Stott et al (2016)

Event definition matters

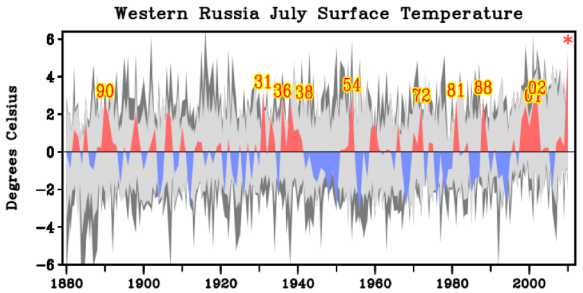


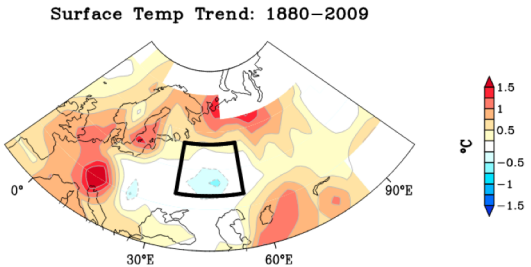
-> more about event definition tomorrow

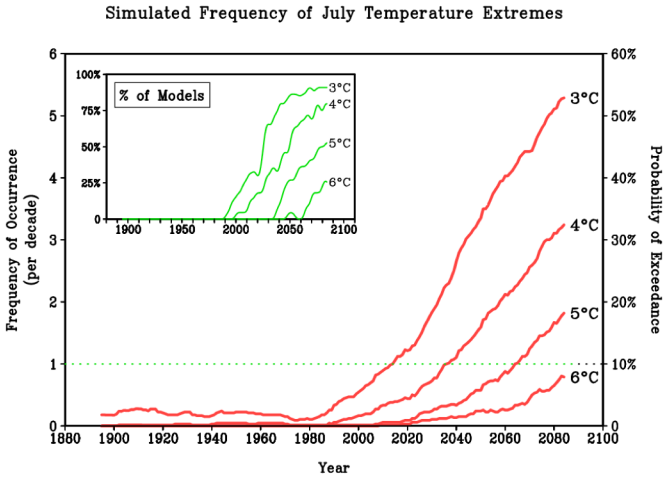
Harrington 2019

Framing matters

"it is very unlikely that warming attributable to increasing greenhouse gas concentrations contributed substantially to the **magnitude** of this heat wave"







Dole et al (2011)

Framing matters

“ For July temperature in Moscow, we estimate that the local warming trend has increased the number of records expected in the past decade fivefold, which implies an approximate 80% **probability** that the 2010 July heat record would not have occurred without climate warming.”

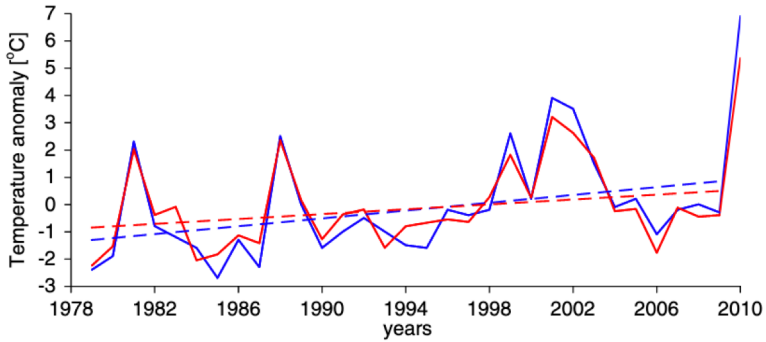


Fig. 5. Comparison of temperature anomalies from remote sensing systems surface data (red; ref. 15) over the Moscow region (35°E–40°E, 54°N–58°N) versus Moscow station data (blue; ref. 21). The solid lines show the average July value for each year, whereas the dashed lines show the linear trend of these data for 1979–2009 (i.e., excluding the record 2010 value). The satellite data have a trend of 0.45 °C per decade for 1979–2009, as compared to 0.72 °C per decade for the Moscow station data.

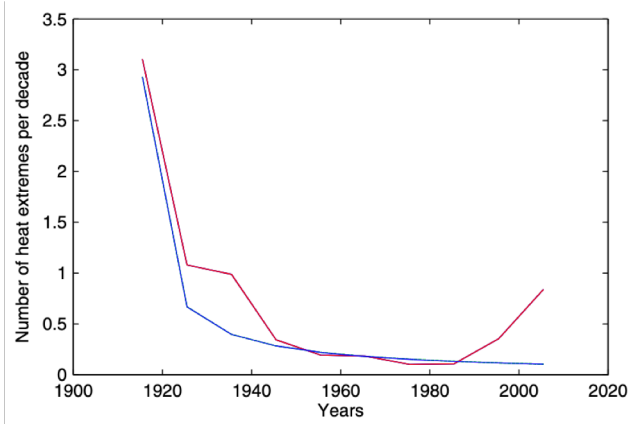
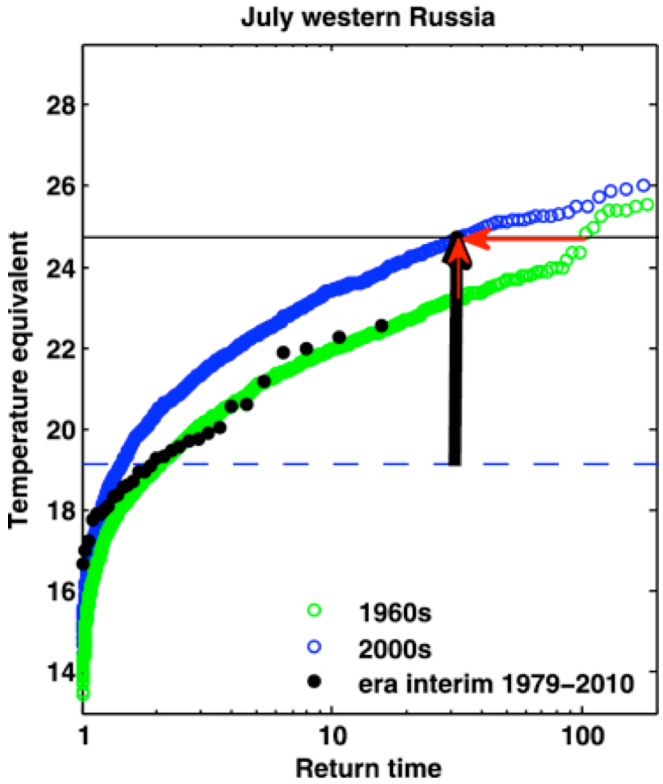


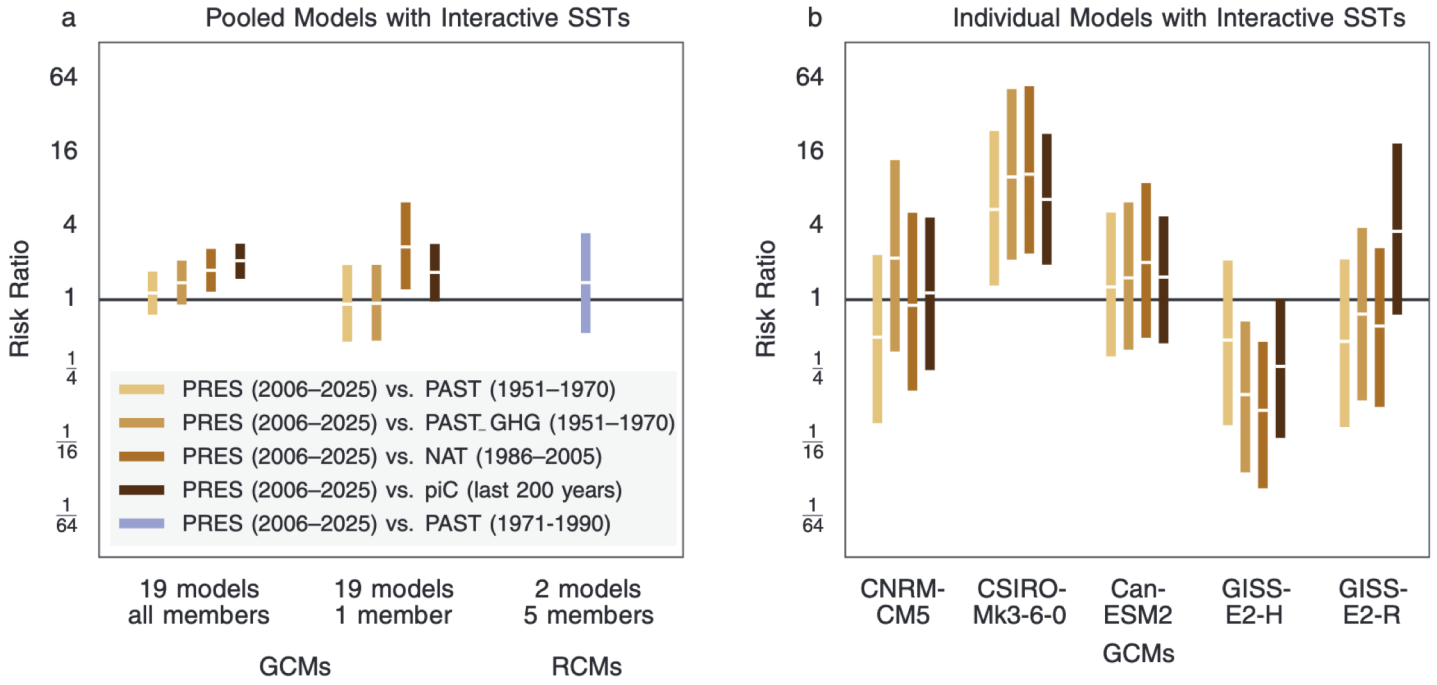
Fig. 4. Expected number of unprecedented July heat extremes in Moscow for the past 10 decades. Red is the expectation based on Monte Carlo simulations using the observed climate trend shown in Fig. 1*E*. Blue is the number expected in a stationary climate (1/*n* law). Warming in the 1920s and 1930s and again in the past two decades increases the expectation of extremes during those decades.

Rahmstorf and Coumou (2011)

Framing matters – Otto et al (2012)



Definition of the counterfactual world matters

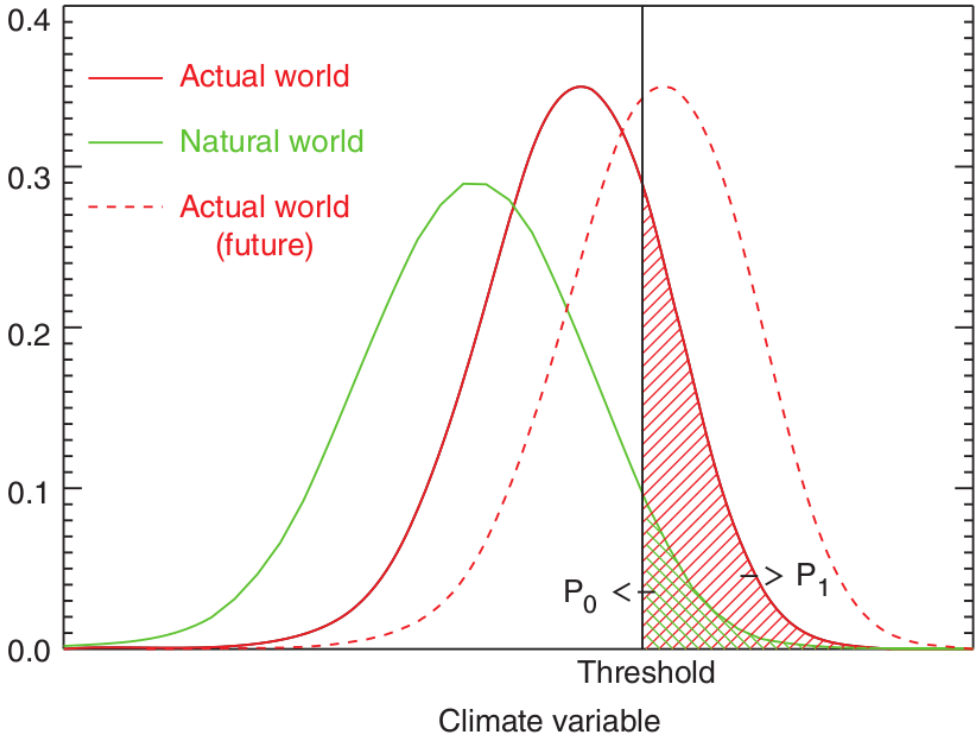


Hauser et al 2015

Different approaches

Approach matters

Risk-based approach



Stott et al (2016)

Risk-based approach

Probability of exceedance in the factual world $p_t^{\mathrm{F}} = \mathbb{P}_t^{\mathrm{F}}(Y_t \geq Y_{2019}^o)$

Probability of exceedance in the counterfactual world $p_t^{\mathrm{C}} = \mathbb{P}_t^{\mathrm{C}}(Y_t \geq Y_{2019}^o)$

Intensity of the event in the factual world $\mathbf{I}_t^{\mathrm{F}} = Q_t^{\mathrm{F}}(1 - p_{2019}^{\mathrm{F}})$

Intensity of the event in the counterfactual world $\mathbf{I}_t^{\mathrm{C}} = Q_t^{\mathrm{C}}(1 - p_{2019}^{\mathrm{F}})$

Probability ration $\mathrm{PR}_t = p_t^{\mathrm{F}}/p_t^{\mathrm{C}}$

Fraction of attributable risk $\mathrm{FAR}_t = 1 - \frac{1}{\mathrm{PR}_t}$

Difference of intensity $\Delta\mathbf{I}_t = \mathbf{I}_t^{\mathrm{F}} - \mathbf{I}_t^{\mathrm{C}}$

-> see tomorrow’s practical on how to calculate them

Risk-based approach

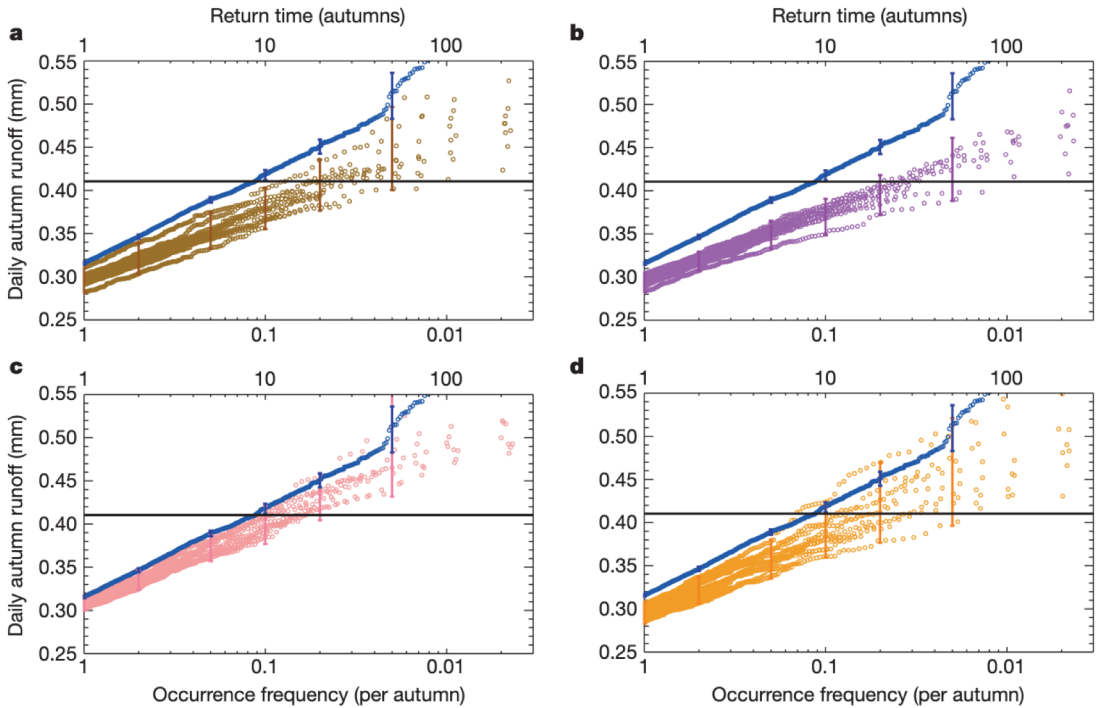


Figure 3 | Change in occurrence frequency of daily river runoff for England and Wales autumn 2000. **a–d**, Occurrence frequency curves of runoff (circles) synthesized from all precipitation simulations in A2000 and A2000N climates. Top axis of each panel is equivalent return time. Each panel shows identical A2000 runoff (blue). A2000N runoffs differ, being in climates generated using attributable SST warming estimates from HadCM3 (**a**; brown), GFDLR30 (**b**; purple), NCARPCM1 (**c**; pink) and MIROC3.2 (**d**; orange), with 10 curves corresponding to equiprobable amplitudes of warming. Bars represent 5–95% confidence intervals (see Methods). Horizontal line marks the highest autumn 2000 runoff synthesized from ERA-40 precipitation (0.41 mm).

Pall et al (2011)

Datasets for EEA

Reanalyses
GCMs -> CMIP5/CMIP6 models
RCMs
-> weather@home
-> CORDEX
…
They all have their limitations

Storyline approach

Disentangling dynamics and thermodynamics

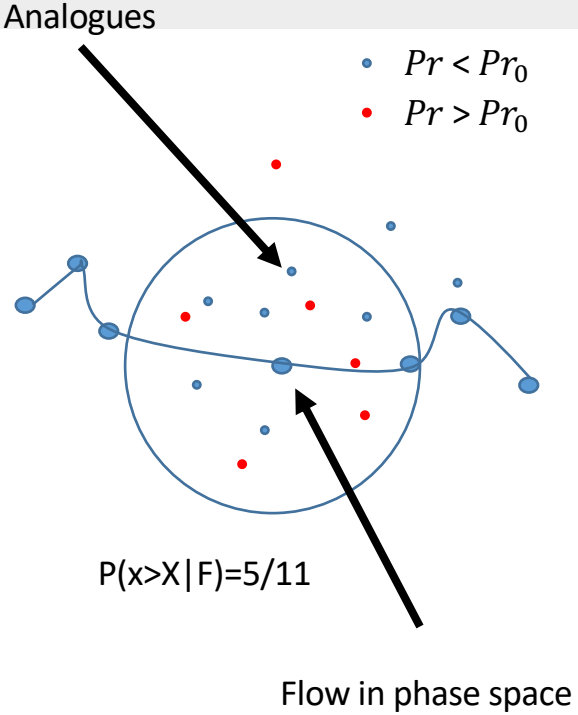
Theoretical basis

How did climate change affect the physical processes leading to the event?
→ Division between dynamics and thermodynamics
Trenberth et al (2015) Nature Clim. Change
Shepherd (2016) Current Climate Change Reports

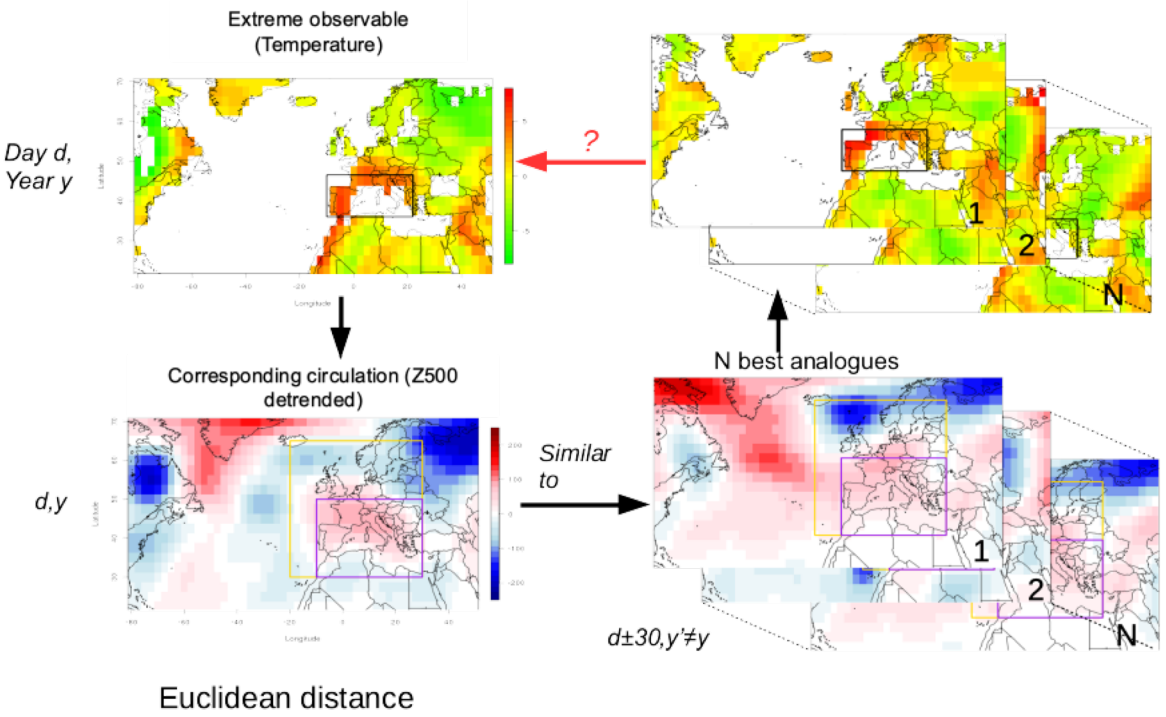
Flow-conditioned probabilities $P(X > X_0|Flow)$ (X=pr, T)

→ To estimates conditional probability of exceedance of a threshold given the flow:

$P(Pr > Pr_0|Flow)$ determined by counting hits in the neighbourhood of the flow in phase space



Flow analogues



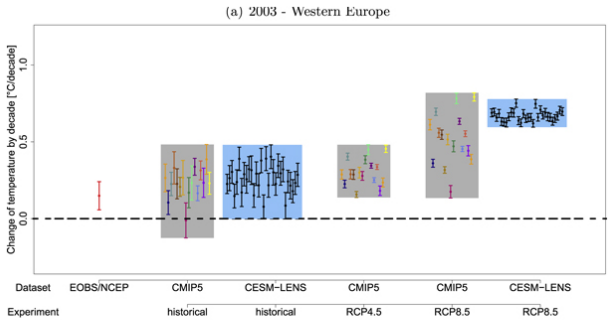
Jézéquel et al. (2018) Clim. Dyn.

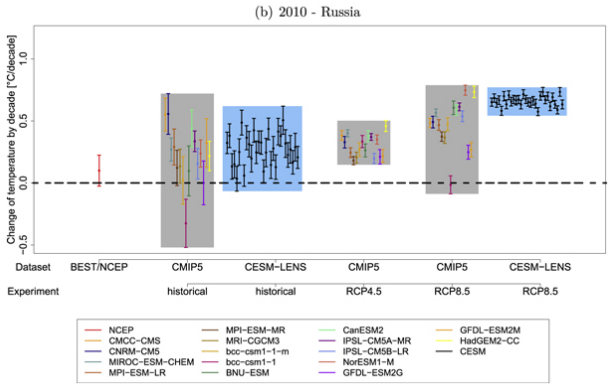
Residual thermodynamical trends

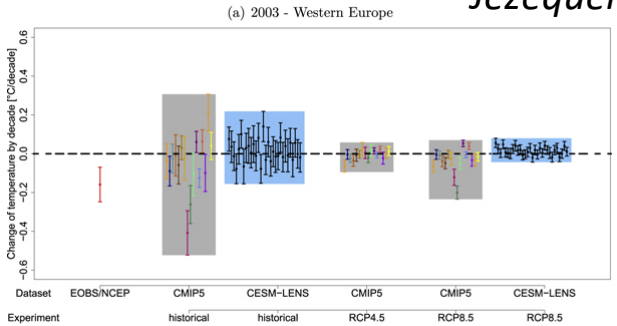
Jézéquel et al 2020

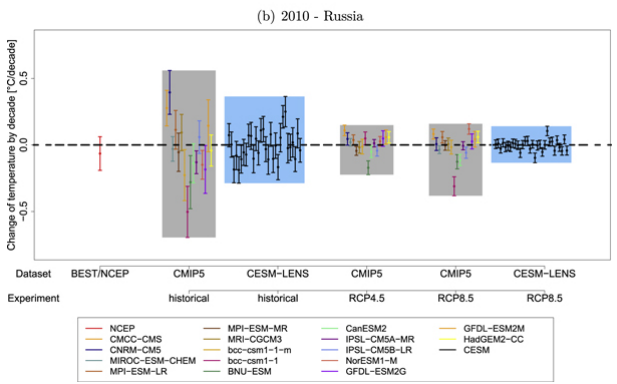
HW 2003

HW 2010





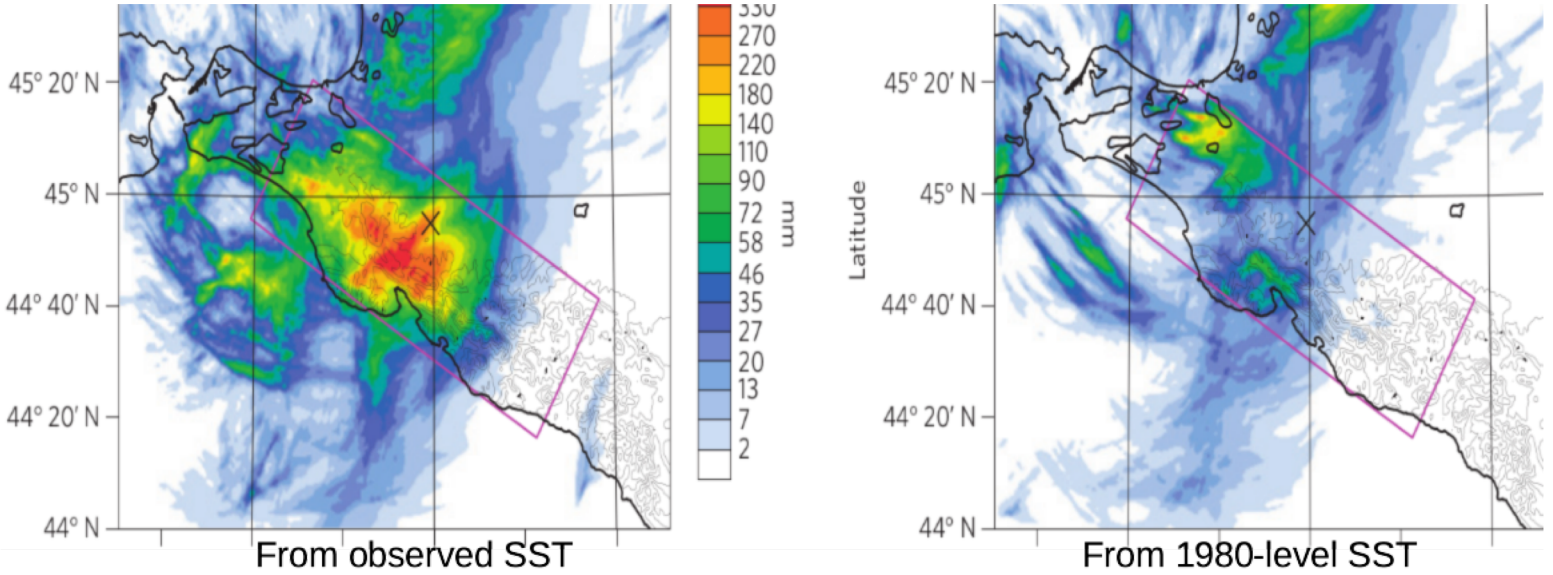




Conditional (Thermodynamical) trend

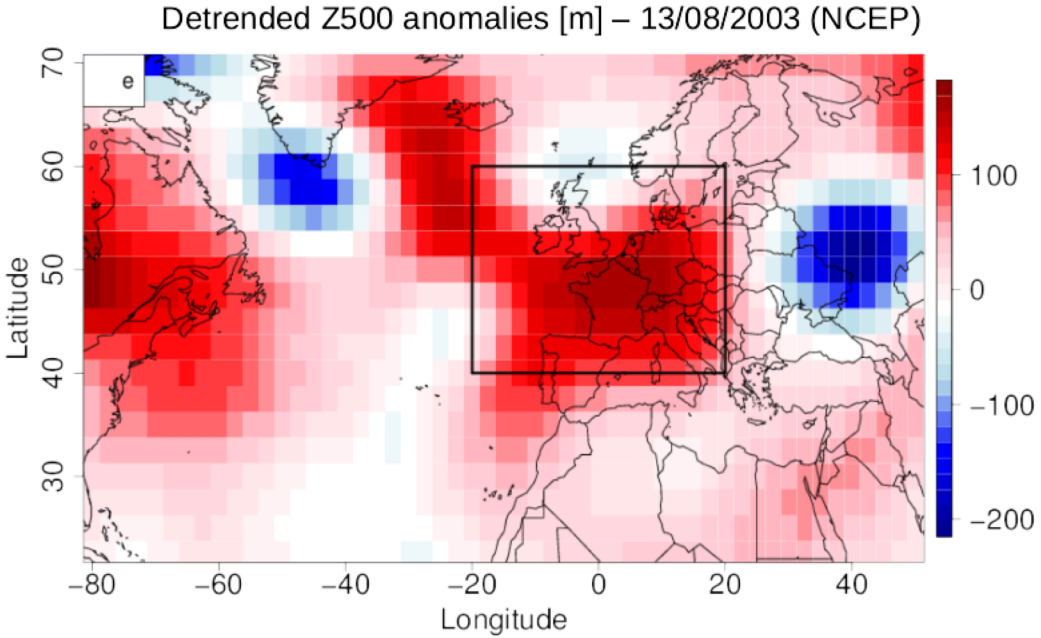
Residual trend

Conditionnal attribution in a model



Meredith et al 2015

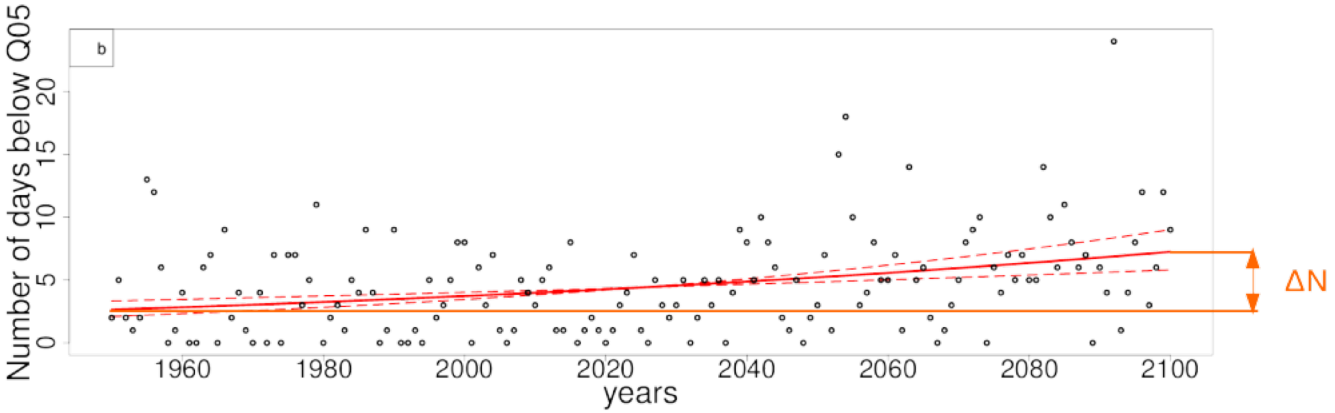
Conditional trends



Does climate change modify the probability of occurrence of this Z500 pattern?

Jézéquel et al. (2018) Env. Res. Let.

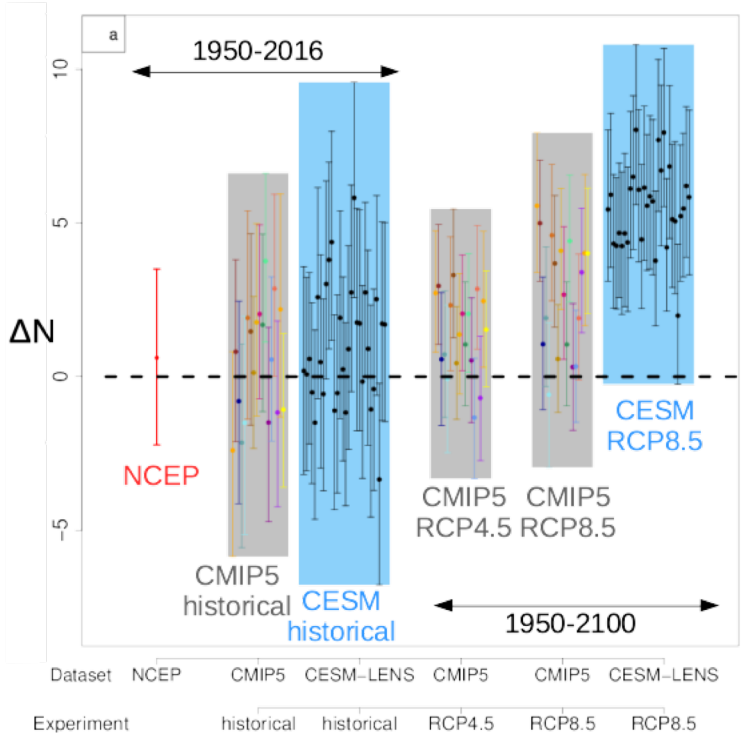
Conditional trends



ΔN: Difference in yearly number of days close to the circulation of interest between the beginning and the end of the time series

Jézéquel et al. (2018) Env. Res. Let.

Conditional trends



- No significant trend on the historical period
- Most models find a significant positive trend for the 2003 heatwave

Jézéquel et al. (2018) Env. Res. Let.

Some further challenges

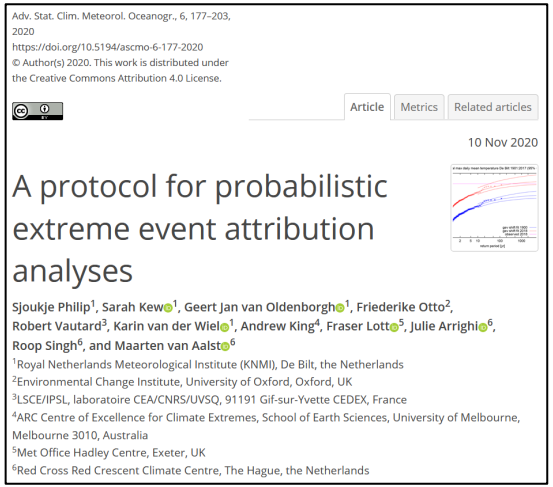
Rapid event attribution

Geert Jan van Oldenborgh

Climate researcher, Royal Netherlands Meteorological Institute

and Friederieke Otto
& other colleagues

- Do it in near real-time
- To have more reach
- Peer-review related questions (many collective discussions)



Adv. Stat. Clim. Meteorol. Oceanogr., 6, 177–203, 2020
https://doi.org/10.5194/ascmo-6-177-2020

Article | Metrics | Related articles

10 Nov 2020

A protocol for probabilistic extreme event attribution analyses

Sjoukje Philip[1], Sarah Kew[1], Geert Jan van Oldenborgh[1], Friederike Otto[2], Robert Vautard[3], Karin van der Wiel[1], Andrew King[4], Fraser Lott[5], Julie Arrighi[6], Roop Singh[6], and Maarten van Aalst[6]

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[5]Met Office Hadley Centre, Exeter, UK
[6]Red Cross Red Crescent Climate Centre, The Hague, the Netherlands

- Trigger conditions
- *Bring together experts*
- Define the event
- Collect observations and available models
- Detection: observation analysis
- Model evaluation
- Attribution: model analysis
- Hazard Synthesis
- Vulnerability and exposure
- Communication summaries

world weather attribution

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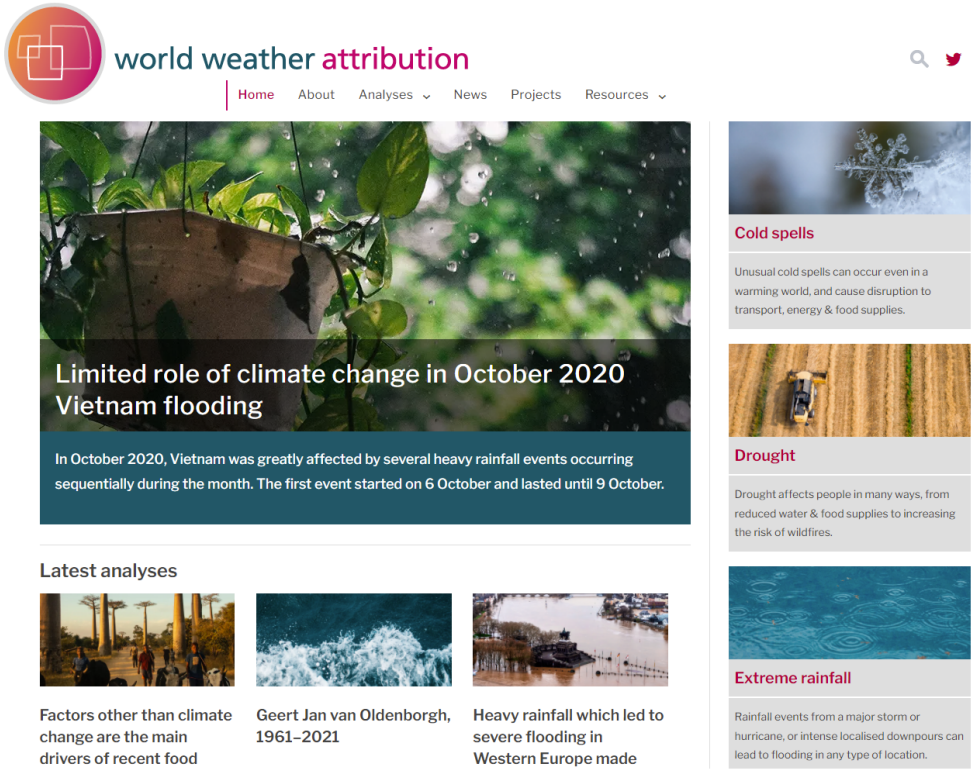
The « world weather attribution » network

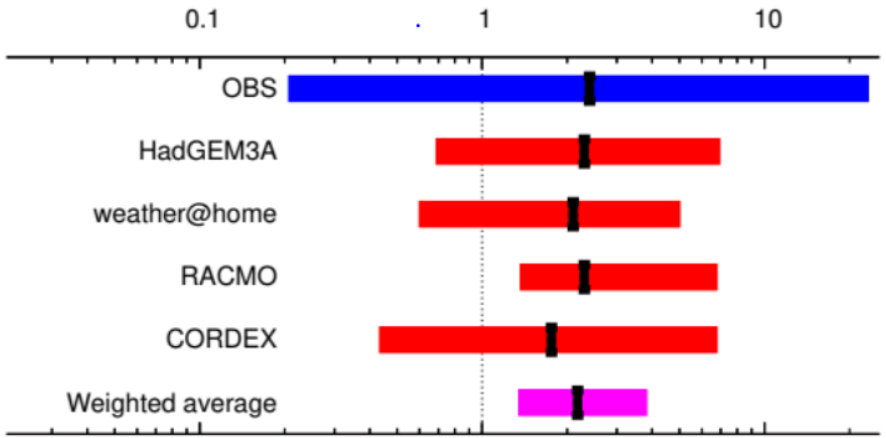


https://www.worldweatherattribution.org

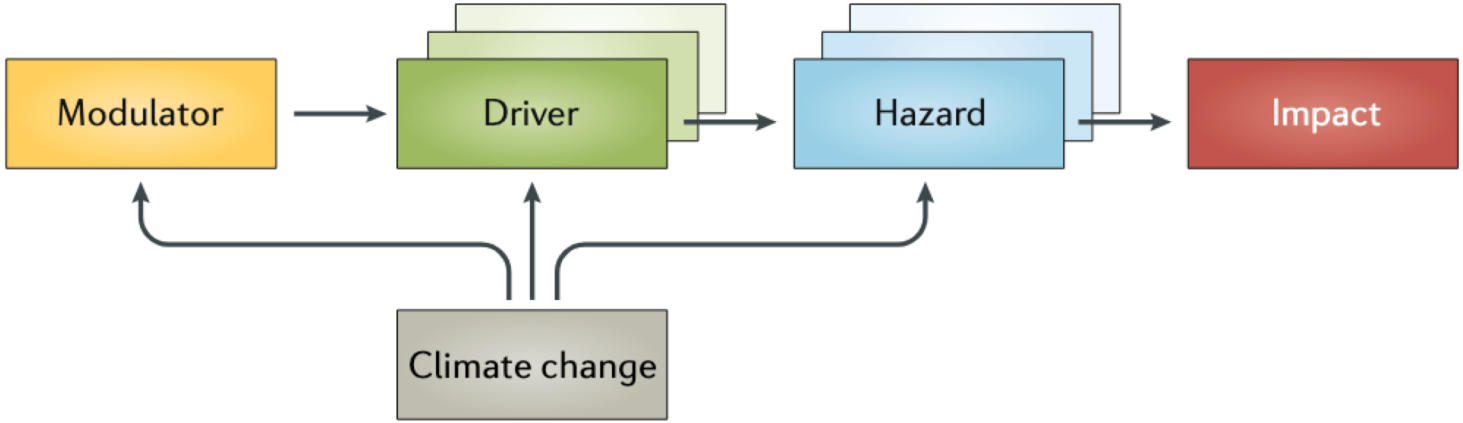
3-day rainfalls that led to Seine river floods

29-30-31 May 2016
~18 mm/day average
over the Seine catchment

Risk ratio of 3-day rainfall exceeding the observed extreme : approximately 2

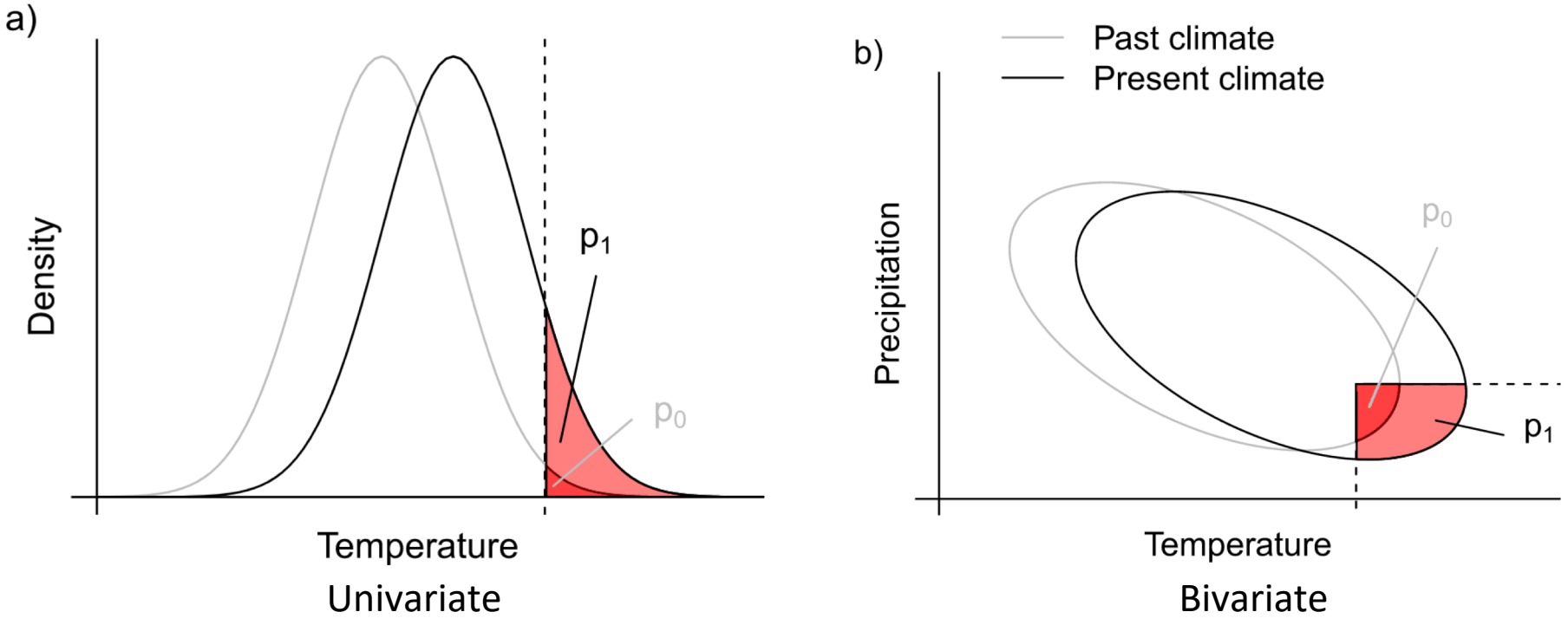


Compound events attribution



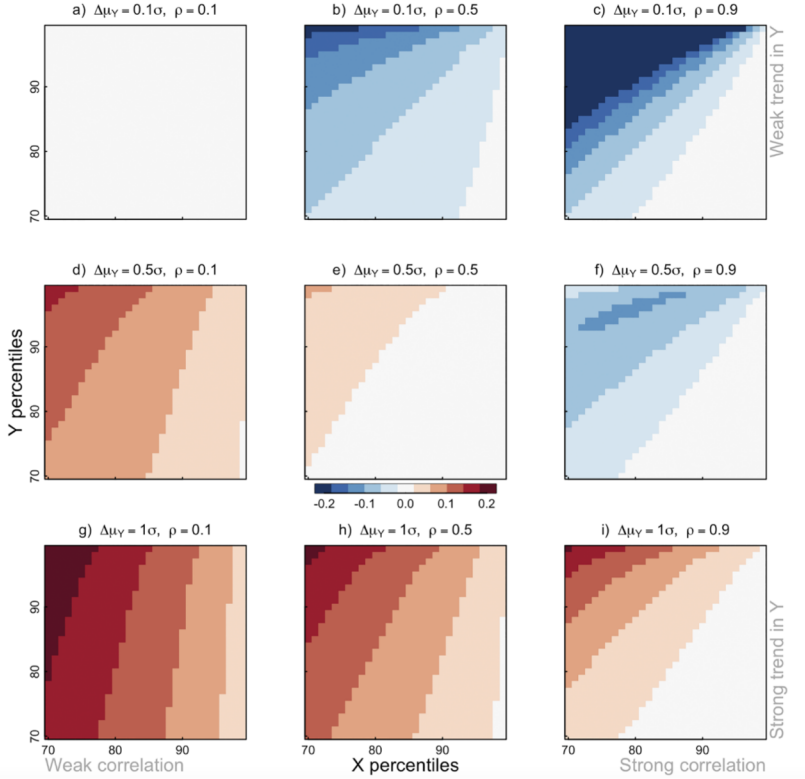
Zscheischler et al 2020

Compound events attribution



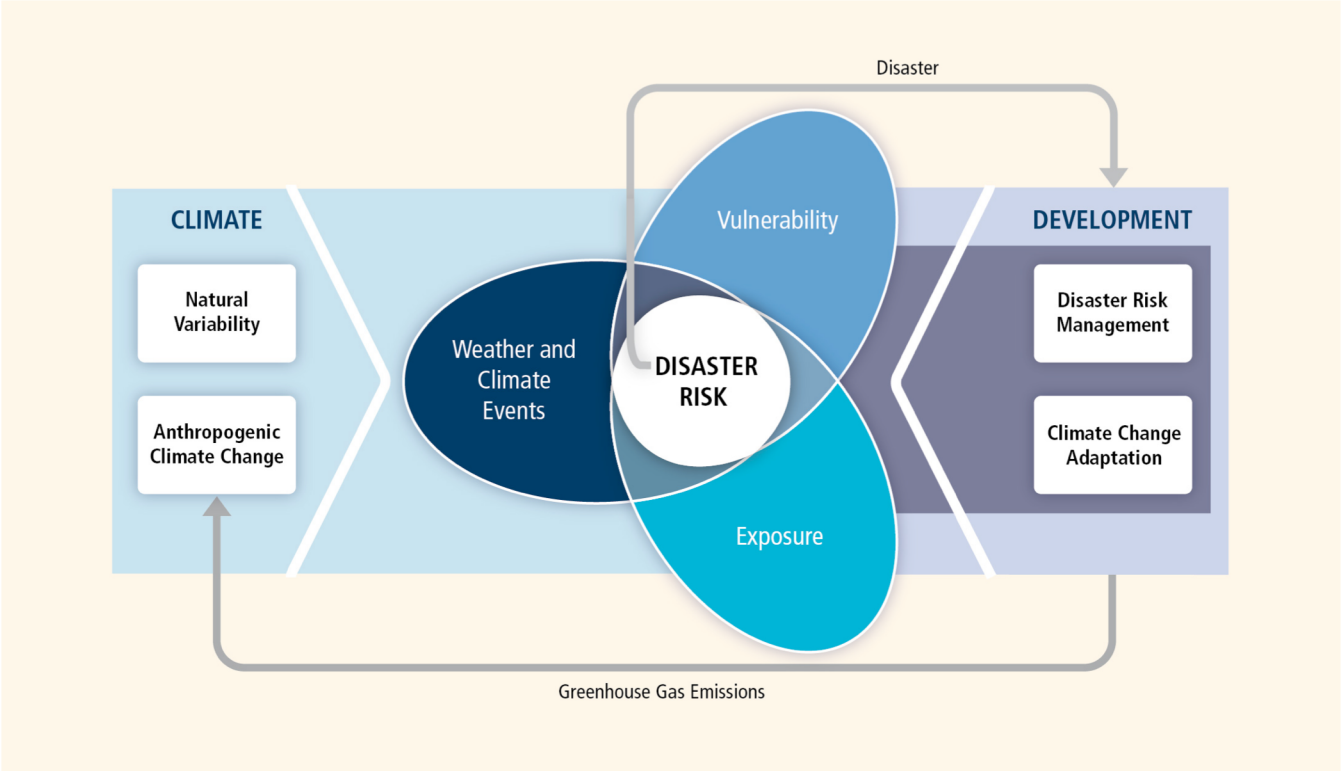
Zscheischler and Lehner 2022

Compound events attribution



Zscheischler and Lehner 2022

Extreme impacts attribution



IPCC

Extreme impacts attribution

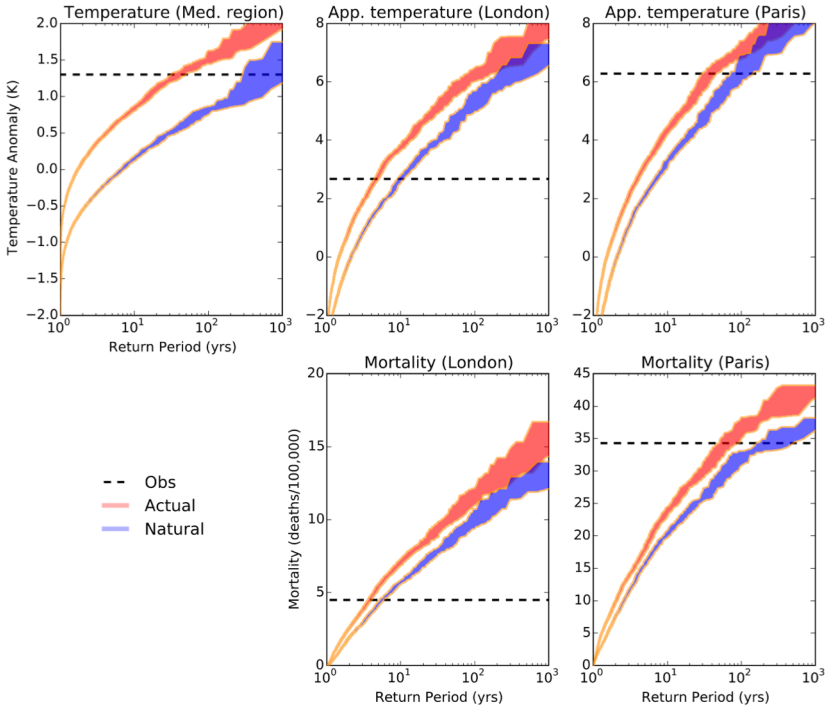
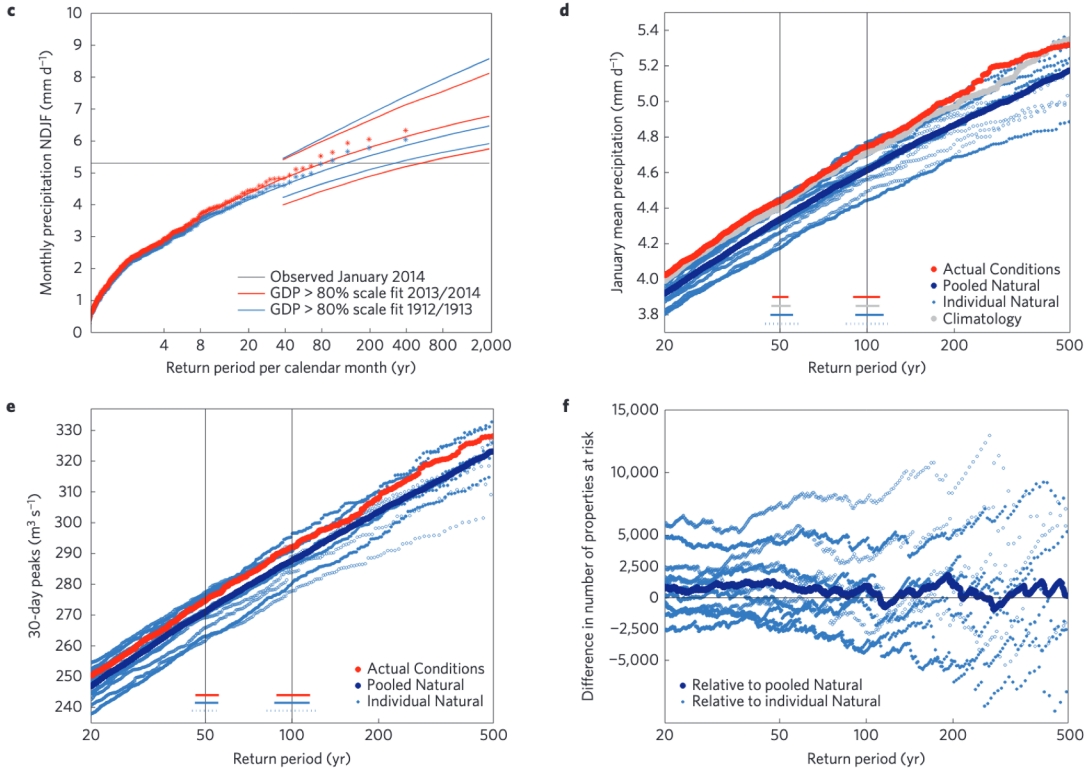


Figure 6. Temperature and mortality return period curves. (top, left) Summer-averaged temperature over the Mediterranean region and (top, middle and right) summer averaged apparent temperature over London and Paris. The bottom panels show the same but for cumulative summer heat-related mortality. Mortality counts are expressed per 100 000 population of the city. 5%–95% confidence intervals are plotted on the return level curves. The dashed line on each panel shows the value of the observed event.

Mitchell et al (2016)

Extreme impacts attribution



Schaller et al (2014)

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