Overview of extreme event impact attribution

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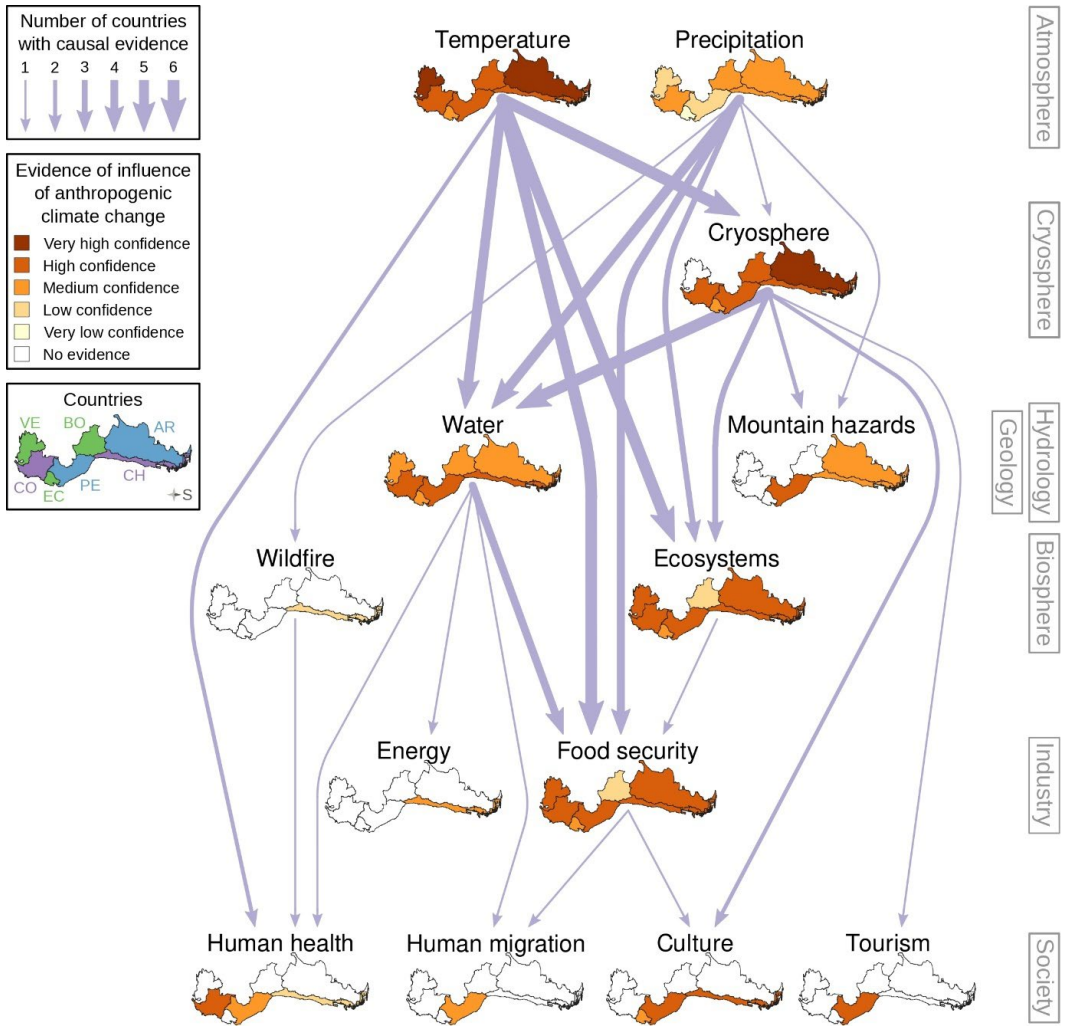
We can now document the cascading impacts of current climate change



Predictions of how climate, hydrology, hazards, ecosystems, industry, and society should have been affected by anthropogenic climate change are confronted by observed changes.

Combination of:

- Ability to make predictions
- Observations
- Predictions and observations agree

Ana Ochoa Sánchez and co, in press

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Extreme event impact attribution

Attribution:

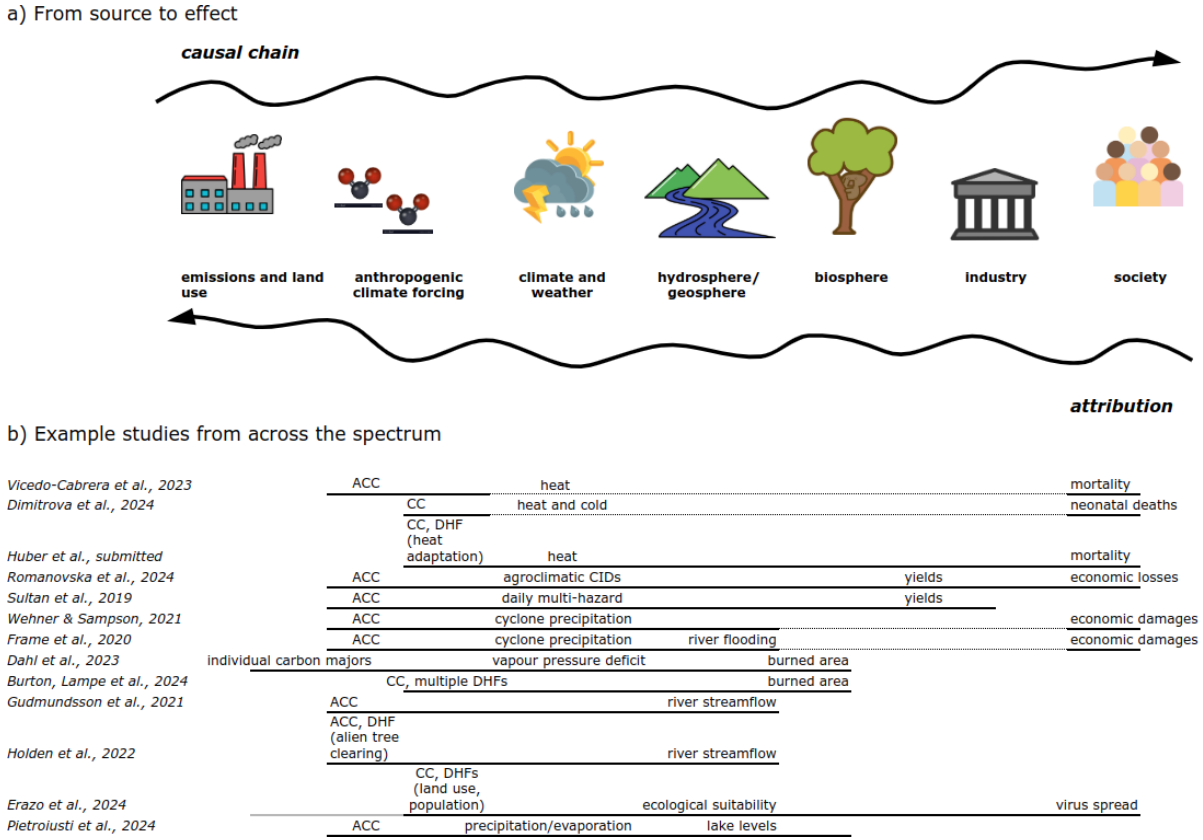
The process of evaluating the contribution of one or more causal factors to observed events.

- IPCC Sixth Assessment Report

Diagnosing causation

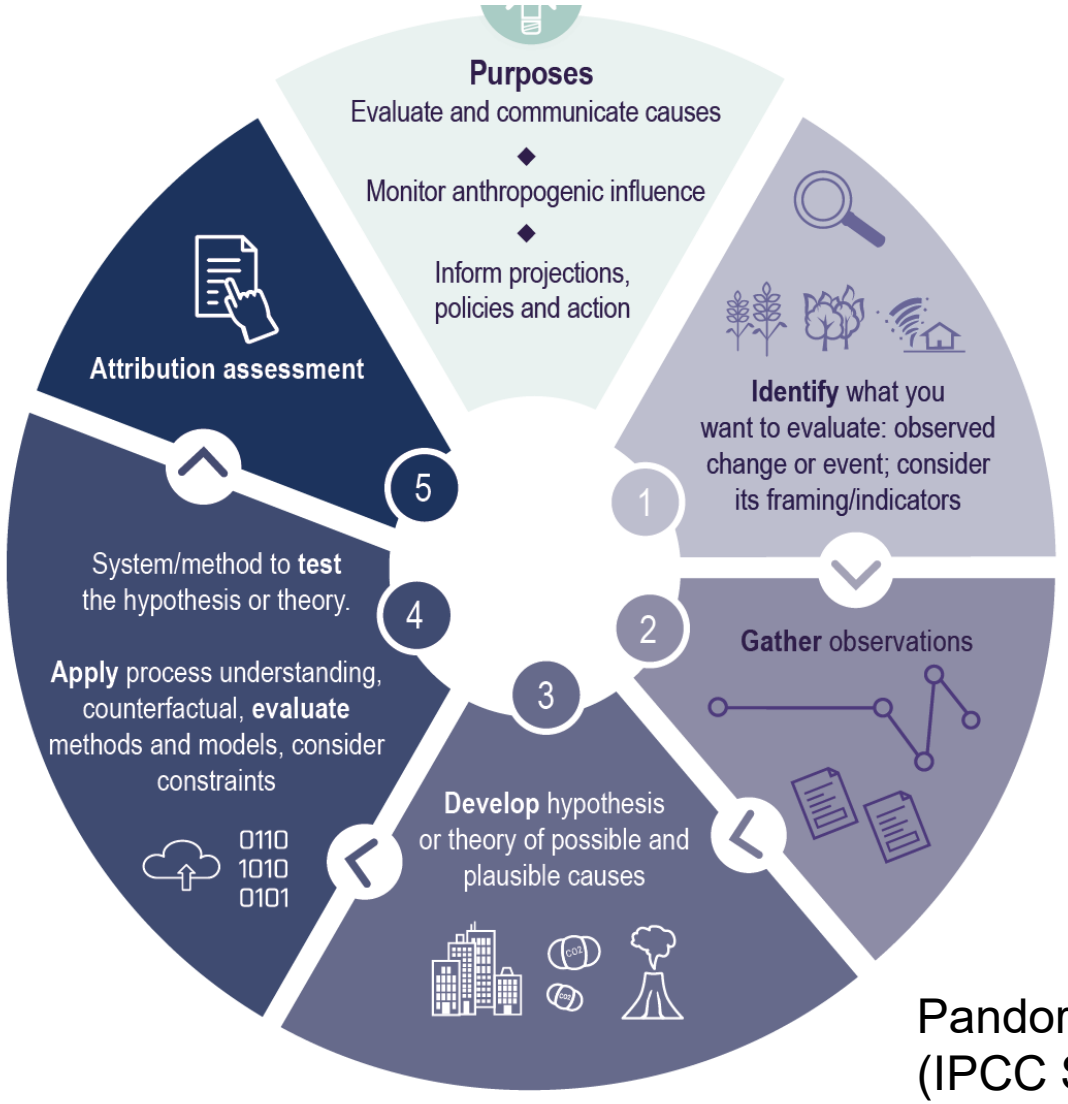
- What caused what
- Climate change in there somewhere

It is about the *present*.



Sabine Undorf and others, submitted

The process of attribution



- Multiple steps in the process
  - Requires observations, some way to develop counterfactual
- Key step: Purpose

Pandora Hope and others (2021)
(IPCC Sixth Assessment Report)

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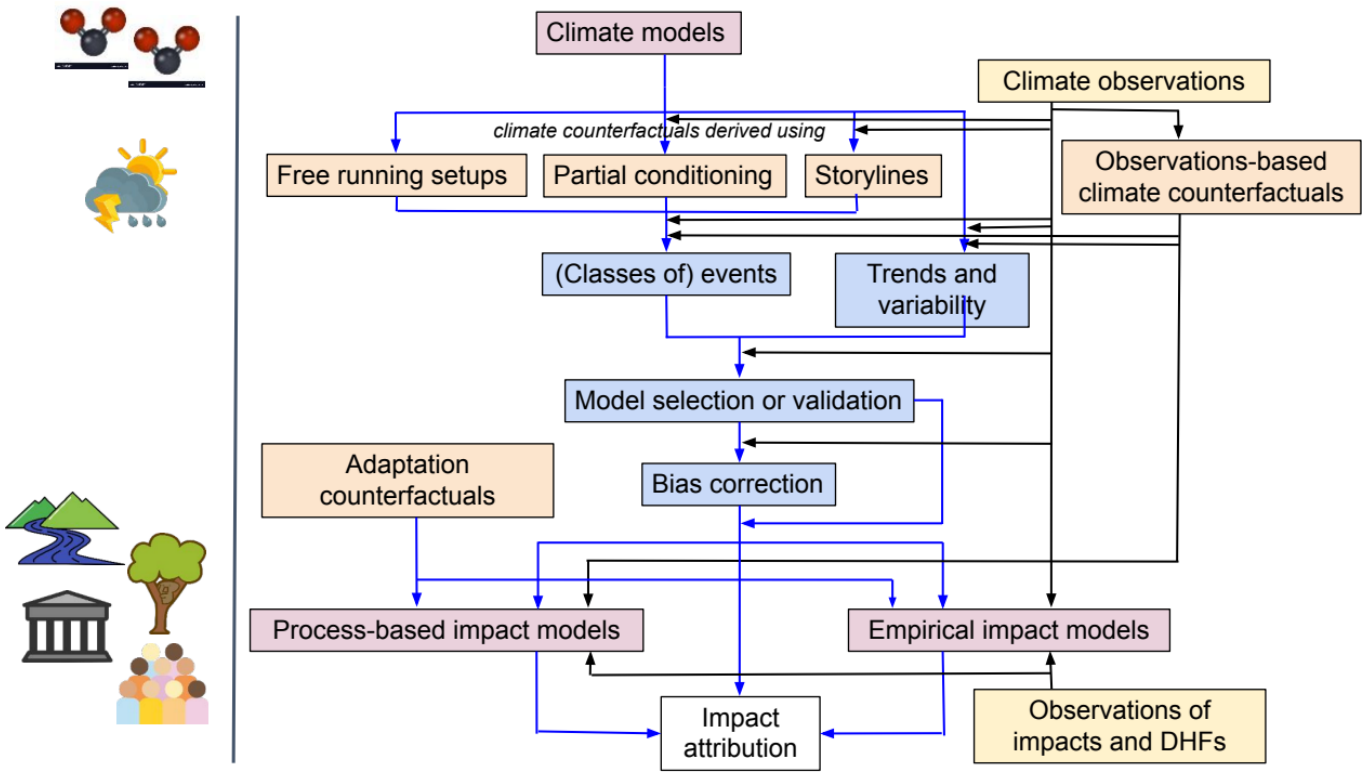
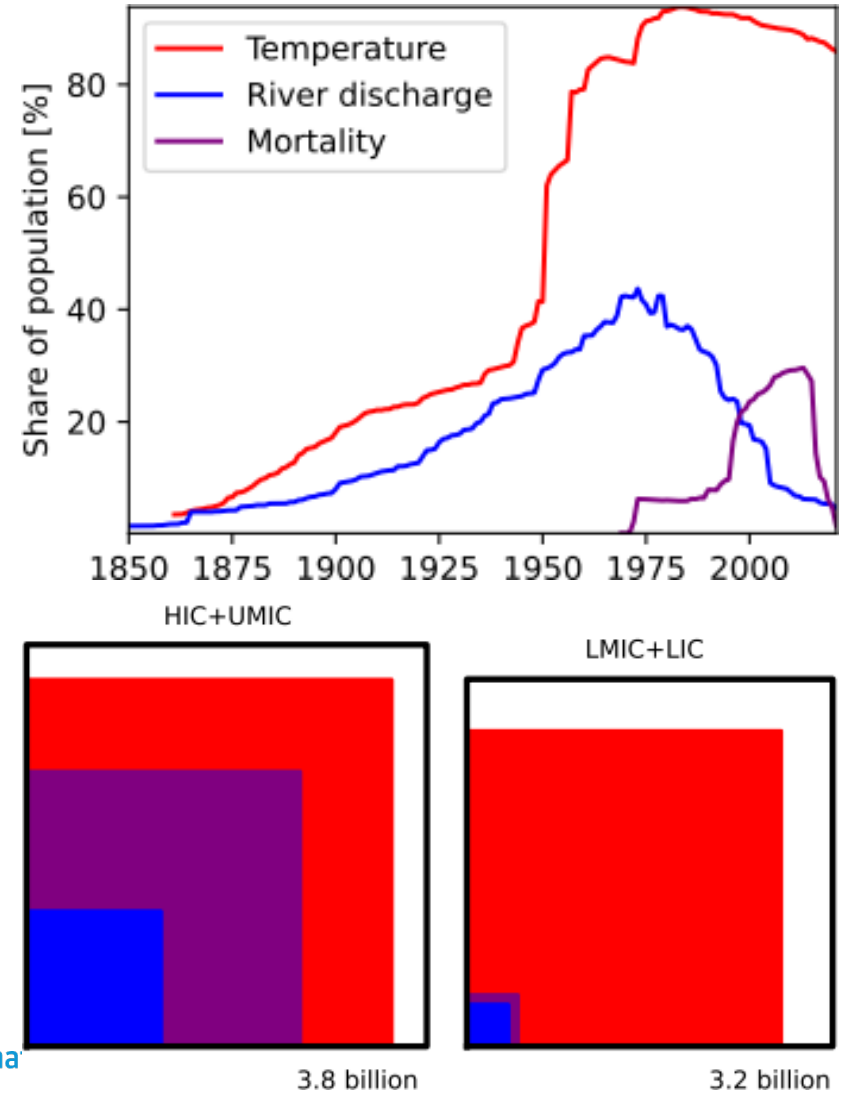
The process of impact attribution



Sabine Undorf and others, submitted

- Requires multiple data sources
  - Observations
  - Simulated data
- Requires identification of some counterfactual
- Not all steps here are required, and some may be duplicated (e.g. impact chain)

Monitoring across disciplines



- Public global databases can be limited, generally held nationally or provincially, sometimes commercially
- Major data access issues, e.g. because of privacy or commercial value
- Different temporal profiles of data coverage
- Different spatial profiles of data coverage
- Very different types of data

Sabine Undorf and others, submitted

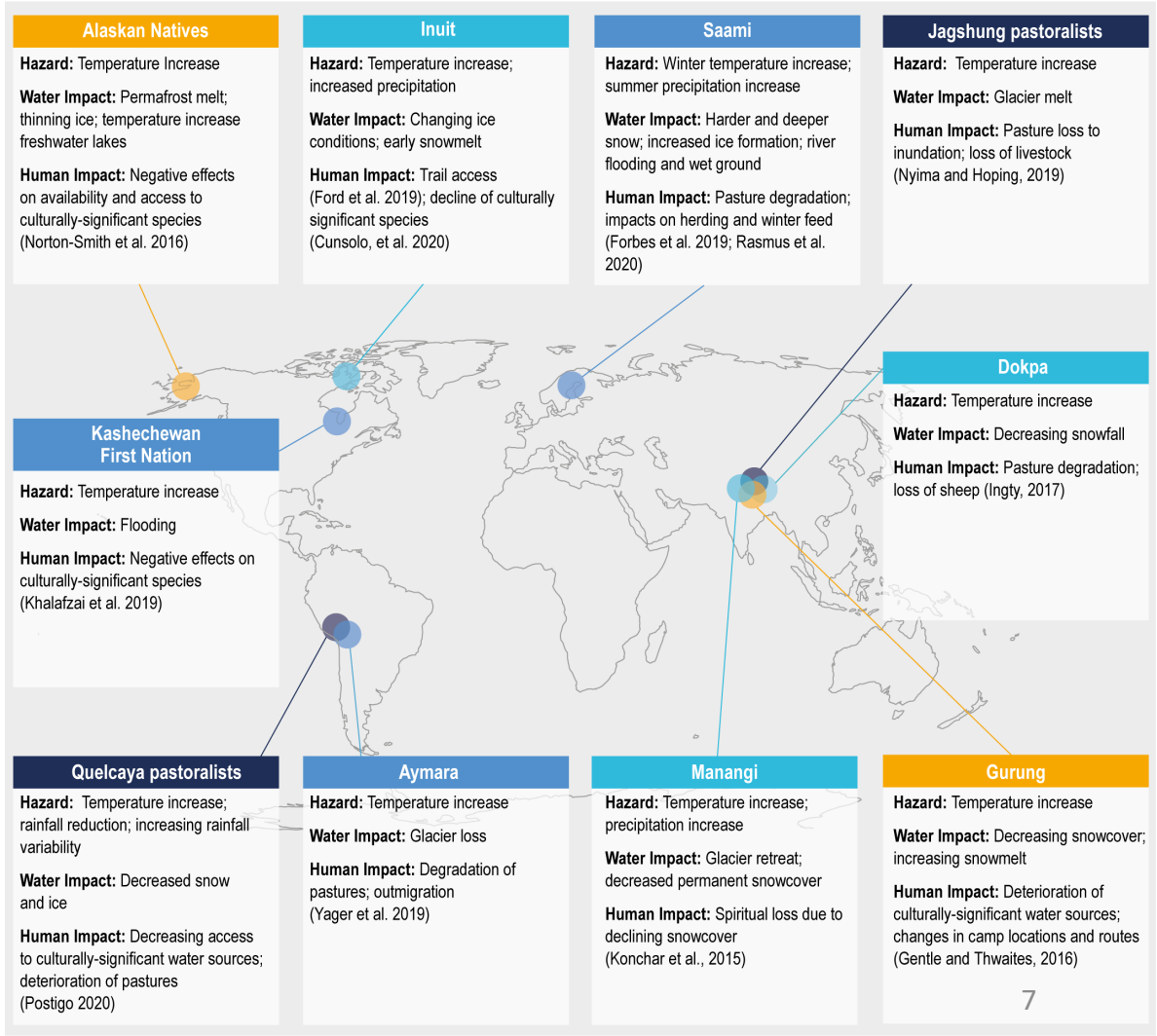
(Share of global population covered by monitoring; bottom higher income versus lower income countries)

Traditional indigenous knowledge

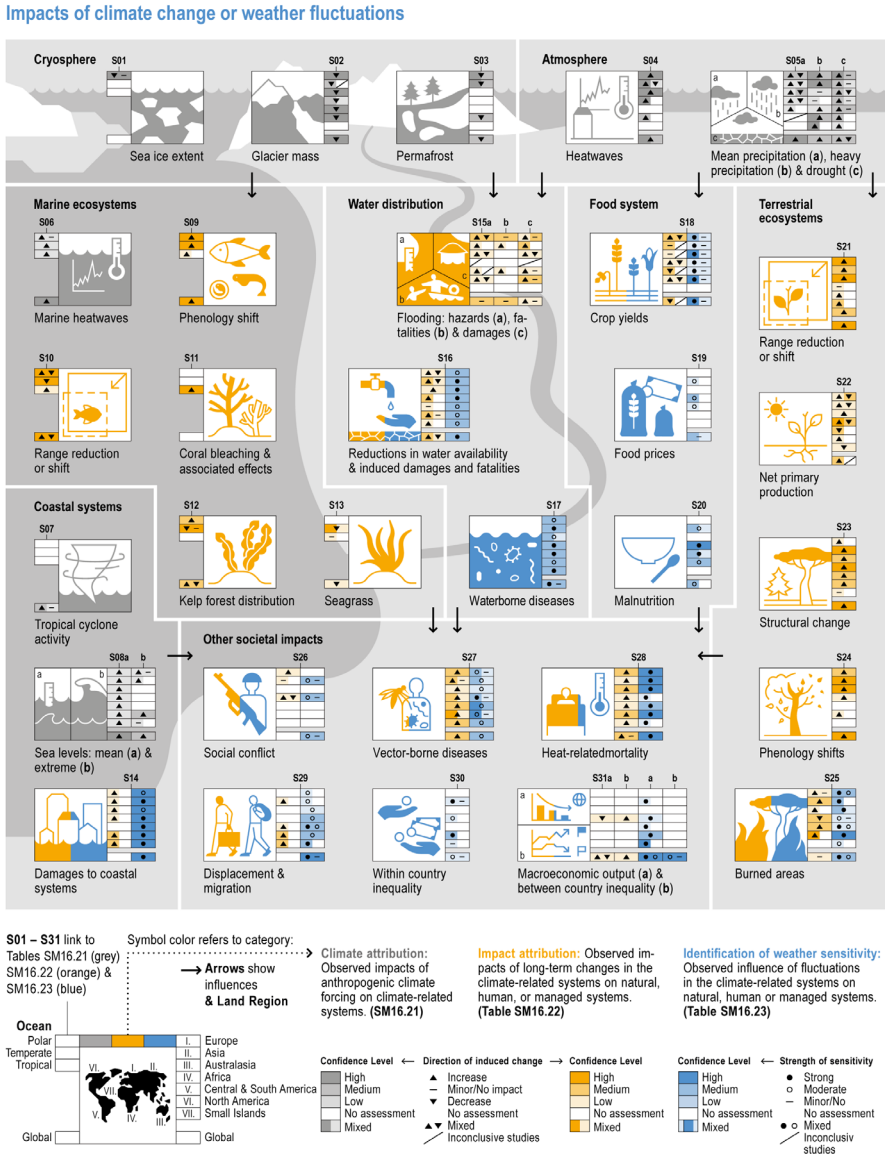
- Attribution can incorporate traditional indigenous knowledge
- Holistic description of why things happen
- Integral to adaptation responses
- Contextualises current and future climate change in the knowledge of generations

Martina Angela Caretta and others (2022) (IPCC Sixth Assessment Report)

Map of selected observed impacts on cultural water uses of Indigenous Peoples of the cryosphere

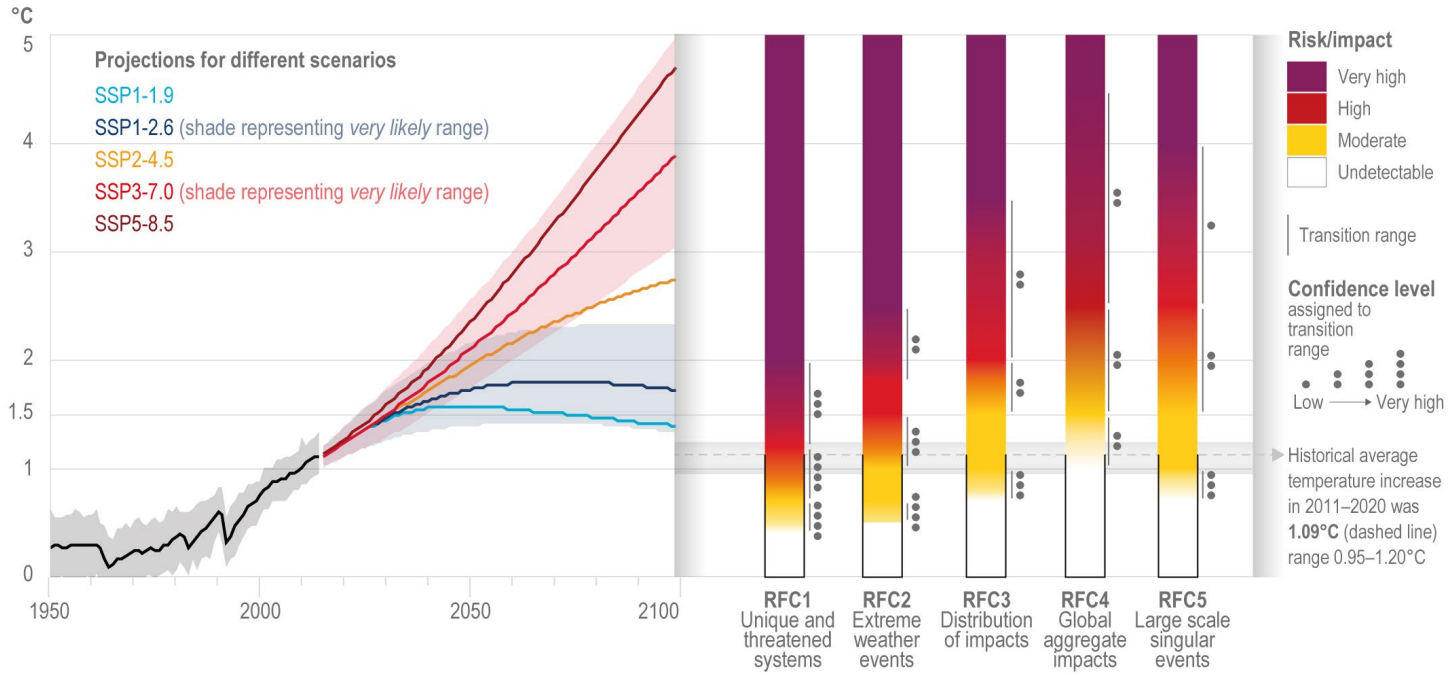


Attribution calibrates predictions



The dependence of risk associated with the Reasons for Concern on the level of climate change

Updated by expert elicitation and reflecting new literature and scientific evidence since AR5 and SR15



Brian O'Neill and others (2022)
(IPCC Sixth Assessment Report)

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What is the outcome/vulnerability?

- A single weather event may have multiple impacts
- But different aspects of that weather event were involved in the different impacts
    - Heat versus drought, duration, extent
- So the purpose (outcome/vulnerability) dictates the definition of the event

Impacts of 2019-2020 Australian wildfires

Fires in southern and eastern Australia from Sep 2019 to Feb 2020

Key

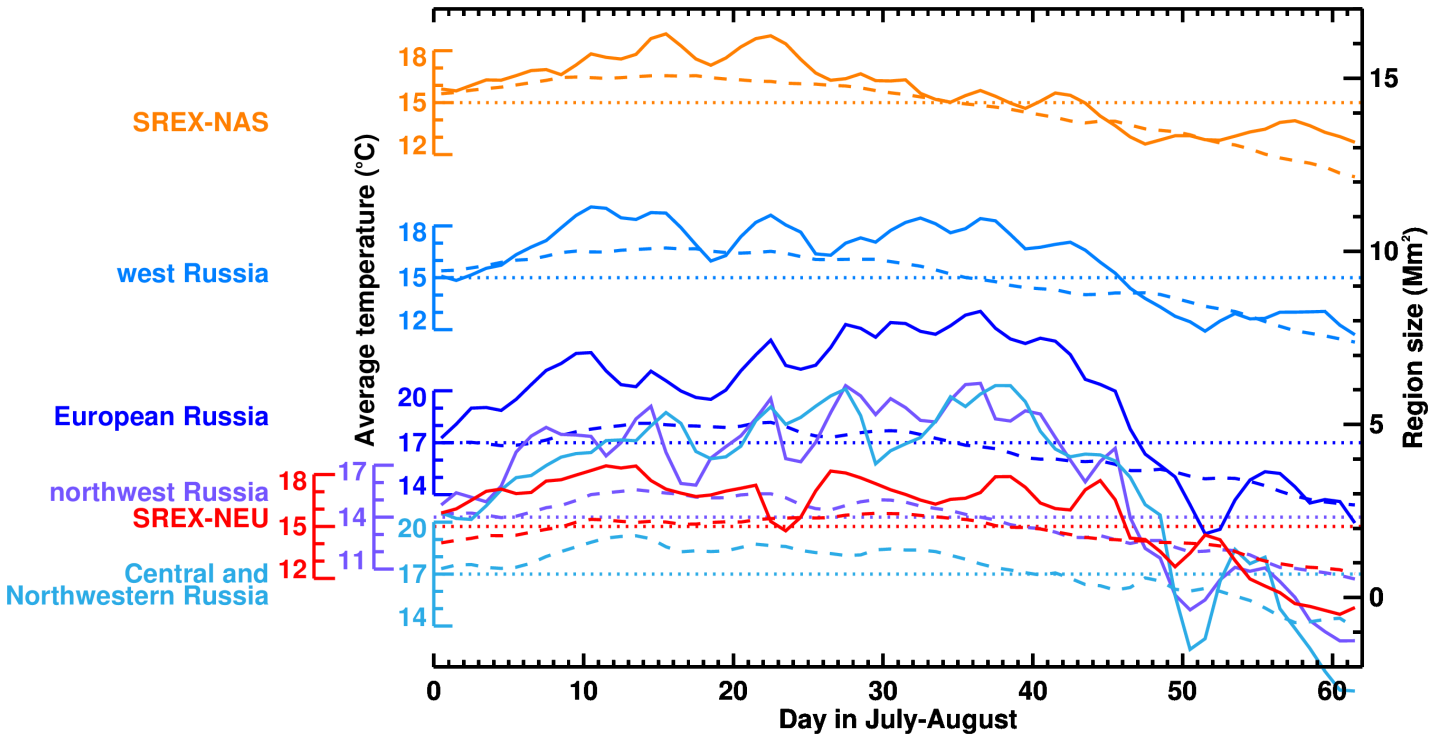
- A Extreme air pollution
- B 5.8 to 8.1 million hectares burned with net emissions of up to 830 million tonnes of CO_2-eq
- C Respiratory illness and disruption of outdoor activities and transport
- D Massive fire-fighting effort, saving many lives and at least 16,000 buildings
- E Building and facility closures, sporting events cancelled, holidays cancelled, workplace closures
- F Degraded and destroyed: Wineries, fruit, livestock, dairy, plantations
- G Loss of or displacement of 3 billion animals, with possible extinctions
- H Change in framework vegetation species and depletion of vegetation habitat resources
- I Smoke and ash transported to New Zealand, affecting air quality and glaciers
- J Destroyed and damaged utilities and infrastructure, e.g. roads closed for weeks, power and communication outages, fuel shortages, back-up generators without diesel, phone batteries run flat
- K Emergency evacuations of thousands of people by road, sea and air involving State Emergency Services and National Defence Force
- L Contamination of rivers and water supply with ash and sediment
- M Economic impacts: Estimates of the national financial impacts are over $8 billion
- N Social impacts: 33 people killed by fires, 429 killed by smoke, 3,103 houses destroyed, social disruption, injuries, exhaustion and mental health issues
- O Environmental impacts: Loss of ecosystem service benefits

Judy Lawrence and others (2022) (IPCC Sixth Assessment Report)

What is the event?

- Obvious meteorological definition may not correspond to the definition relevant for the outcome/vulnerability
- Does this mean we have a trade-off between specificity, generality, and relevance?

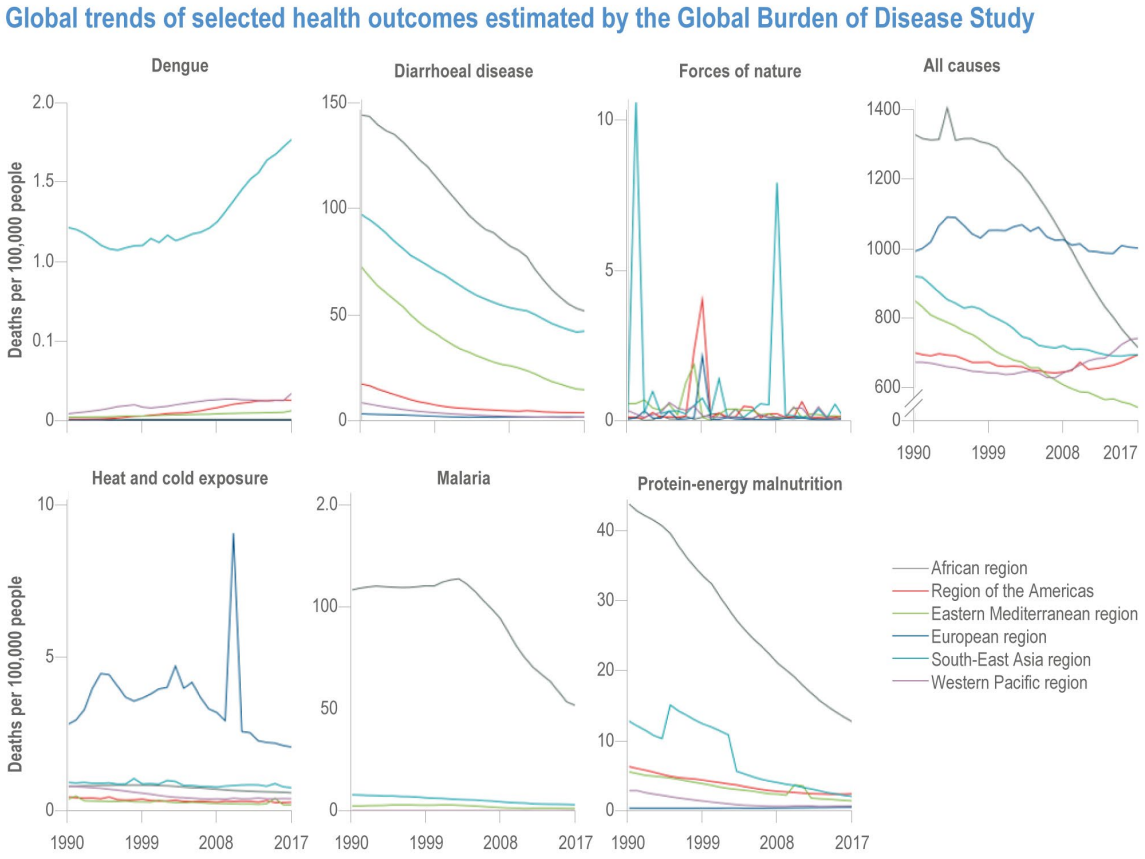
July-August 2010 temperatures over Russia



Language: when attribution is not attribution

- With multi-disciplinarity comes language issues
  - Rather basic terms used in extreme weather event (impact) attribution, like “attribution” and “model”, are not used or mean something different in other disciplines
- There is lot of attribution (or attribution-relevant) information out there that is not clearly labeled for us

Contributing factors everywhere



- We live in a changing world
- The existence of, or changes in, various contributing/risk factors influence an outcome
- Some of these might be classed in the “to blame” category, but many “just are”
- Does impact attribution research need to include them to be relevant? Is it something to be done separately, labelled as something else? Or both?

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Guéladio Cissé and others (2022)

(IPCC Sixth Assessment Report)

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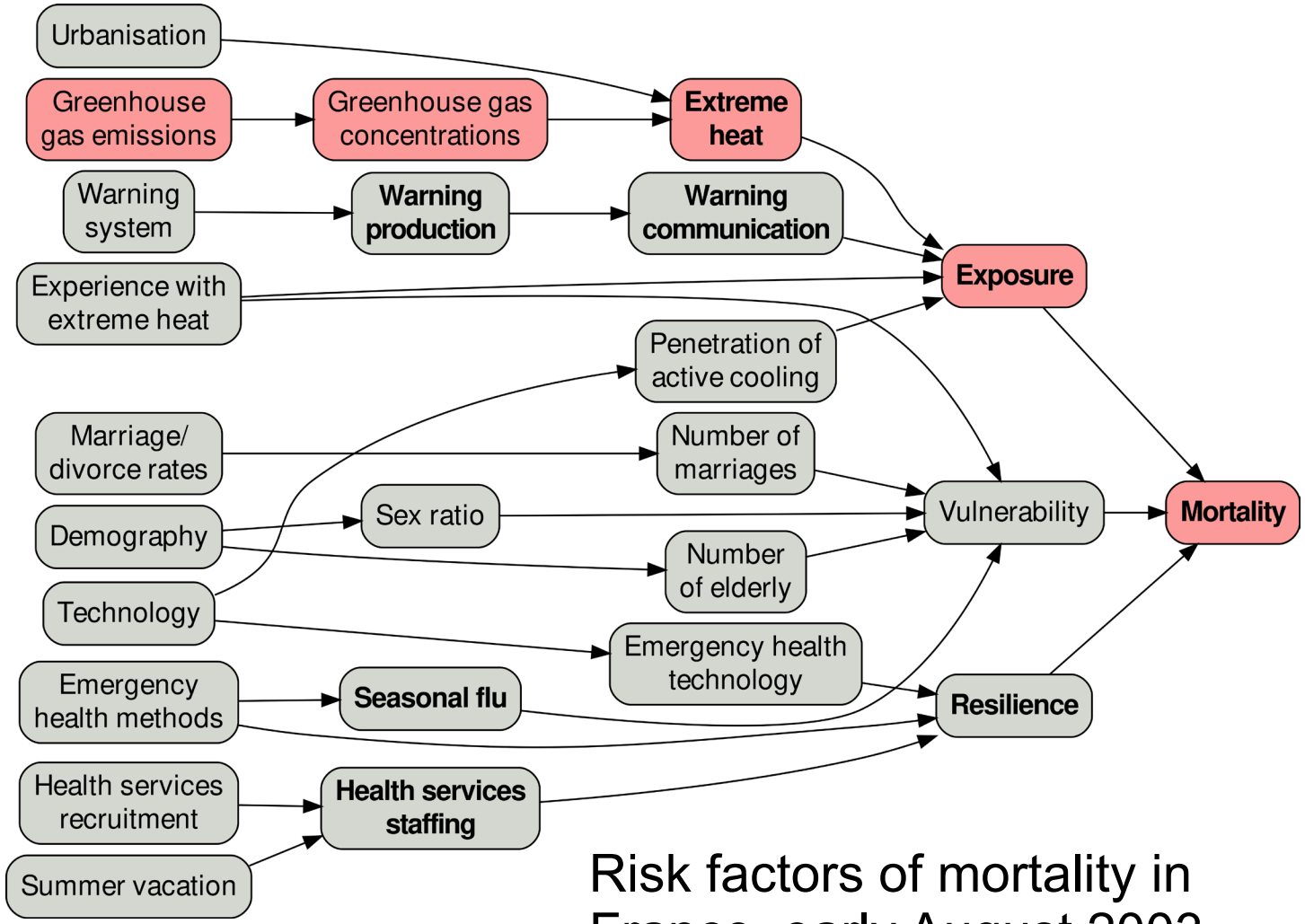
What is the remit of impact attribution?

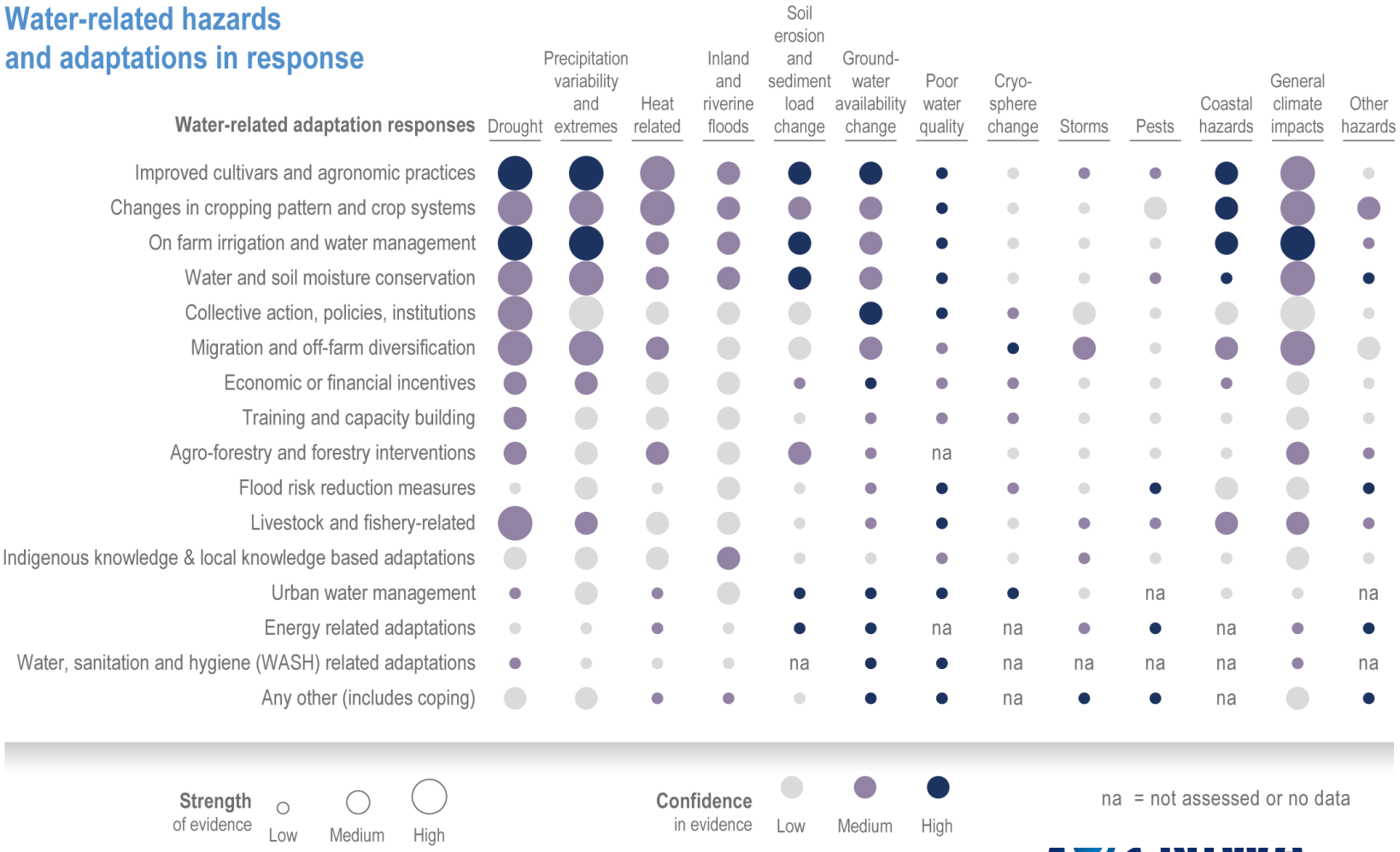


Risk factors of mortality in France, early August 2003
Red: Diagnosing the effect of weather event
Bold: "Events" of possible interest

- What part of this diagram is impact attribution?
- Climate, public health, public policy, disaster risk reduction researchers will have have different terms for all or part of this diagram
- If all of it is impact attribution, then what is "the event"?

We can now monitor adaptation

- How did the outcome(s) of this extreme weather event differ from what it might have been had we not implemented that adaptation measure?
- Is this an impact attribution question? If not, does impact attribution have role?



Martina Angela Caretta and others (2022) (IPCC Sixth Assessment Report)

Don’t panic

- Extreme event impact attribution is multi-disciplinary, which makes it hard in practice
  - But not impossible!
- An impact attribution study can get very complicated very quickly
  - Just remember the purpose
  - The purpose sets strict requirements on what needs to be done, but also sets clear boundaries

References

- Caretta, M. A. and others. 2022. *Water*. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 10.1017/9781009325844.006
- Cissé, G. and others. 2022. *Health, Wellbeing, and the Changing Structure of Communities*. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 10.1017/9781009325844.009
- Fouillet, A. and others. 2006. Excess mortiality related to the August 2003 heat wave in France. International Archives of Occupational and Environmental Health, 80, 16-24
- Fouillet, A. and others. 2008. *Has the impact of heat waves on mortality changed in France since the European heat wave of summer 2003? A study of the 2006 heat wave*. International Journal of Epidemiology, 37, 309-317
- Hémon, D. and E. Jougla. 2003. *Surmortalité liée à la canicule d'août 2003 - Raport d'étape: Estimation de la surmortalité et principales caractéristiques épidémiologiques*. Institut national de la santé et de la recherche médicale, https://www.inserm.fr/wp-content/uploads/2017-11/inserm-rapportthematique-surmortalitecaniculeaout2003-rapportetape.pdf
- Hope, P. and others. 2021. *Attribution*. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 204-206, 10.1017/9781009157896.003
- Jones, G. S. and others. 2008. *Human contribution to rapidly increasing frequency of very warm Northern Hemisphere summers.* Journal of Geophysical Research, 10.1029/2007JD008914
- Lalande, F. and others. 2003. *Mission d'expertise et d'évaluation du système de santé pendant la canicule 2003*. Ministère de la santé, de la famille, et des personnes handicapées, Paris, France.
- Lawrence, J. and others. 2022. *Australasia*. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. 10.1017/9781009325844.013
- Mitchell, D. and others. 2016. Attributing human mortality during extreme heat waves to anthropogenic climate change. Environmental Research Letters, 10.1088/1748-9326/11/7/074006
- O'Neill, B. and others (2022). *Key Risks Across Sectors and Regions*. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 10.1017/9781009325844.025
- Perkins, S. E. and others. 2012. Increasing frequency, intensity and duration of observed global heatwaves and warm spells. Geophysical Research Letters, 10.1029/2012GL053361
- Ochoa-Sánchez, A. and others. 2025. *Detection and attribution of climate change impacts on coupled natural-human systems in the Andes*. Communications Earth & Environment, in press.
- Perkins-Kirkpatrick, S. E. and others. 2022. *On the attribution of the impacts of extreme weather events to anthropogenic climate change*. Environmental Research Letters, 10.1088/1748-9326/ac44c8
- Philip, S. and others. 2020. *A protocol for probabilistic extreme event attribution analyses*. Advances in Statistical Climatology, Meteorology and Oceanography, 10.5194/ascmo-6-177-2020
- Prioux (2005). Recent demographic developments in France. Population-E, 60, 371-414
- Rey, G. and others. 2006. *The impact of major heat waves on all-cause and cause-specific mortality in France from 1971 to 2003*. International Archives of Occupational and Environmental Health, 80, 615-626
- Seneviratne, S. I. and others. 2012. *Changes in climate extremes and their impacts on the natural physical environment*. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, 109-230, Cambridge University Press
- Stone, D. A. 2019. *A hierarchical collection of political/economic regions for analysis of climate extremes*. Climatic Change, 10.1007/s10584-019-02479-6
- Stone, D. A. and others. 2021. *The question of life, the universe, and event attribution*. Nature Climate Change, 1038/s41558-021-01012-x
- Stott, P. A. and others. 2004. *Human contribution to the European heatwave of 2003*. Nature, 432, 610-614
- Undorf, S. and others. 2025. *Approaches and challenges in attributing climate change impacts*. Submitted. (sabine.undorf@pik-potsdam.de)
- van Oldenborgh, G. J. and others. 2021. *Pathways and pitfalls in extreme event attribution*. Climatic Change, 10.1007/s10584-021-03071-7