Applying Attribution Science to Cultural Heritage Impact Assessment

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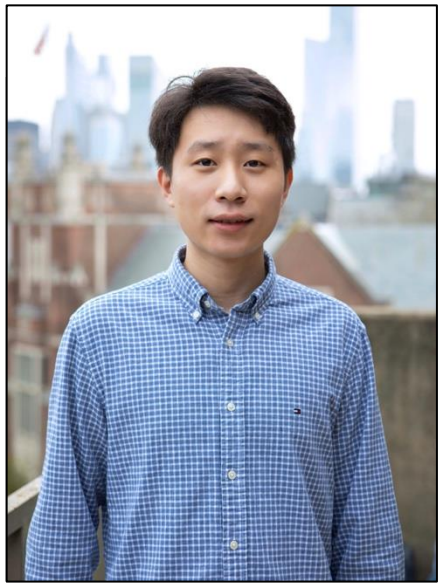

An ‘incomplete’ climate change narrative for heritage

- ‘Climate change is the fastest-growing global threat to the world’s natural and cultural heritage’ (Day et al., 2020).

- ‘Either directly or indirectly, all World Heritage properties are or will be impacted by climate change... It is now the single largest threat to all cultural and natural heritage sites across the planet’ (Megarry, 2022).

UNESCO, World Heritage Convention

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Original article

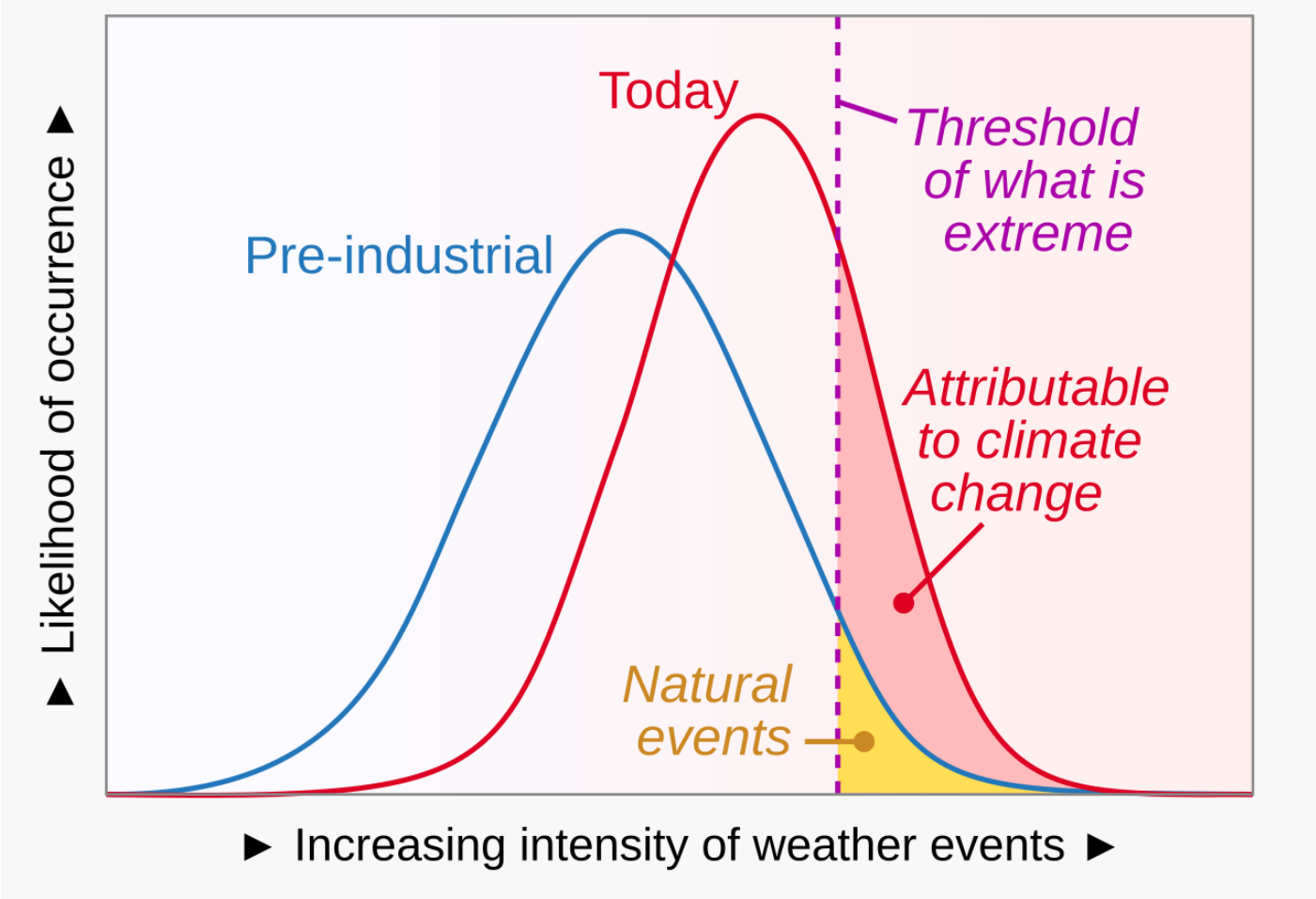
Humans have already endangered their shared cultural heritage by amplifying extreme weather events

Shixin Zhao[a,*], An Liu[b], Scott Allan Orr[a], Chris Brierley[b]

What are the attributable impacts for cultural heritage?

- Are climate impacts always adverse for heritage?
- How much of these impacts are attributable to human activities?
- How much can be explained by natural variability?

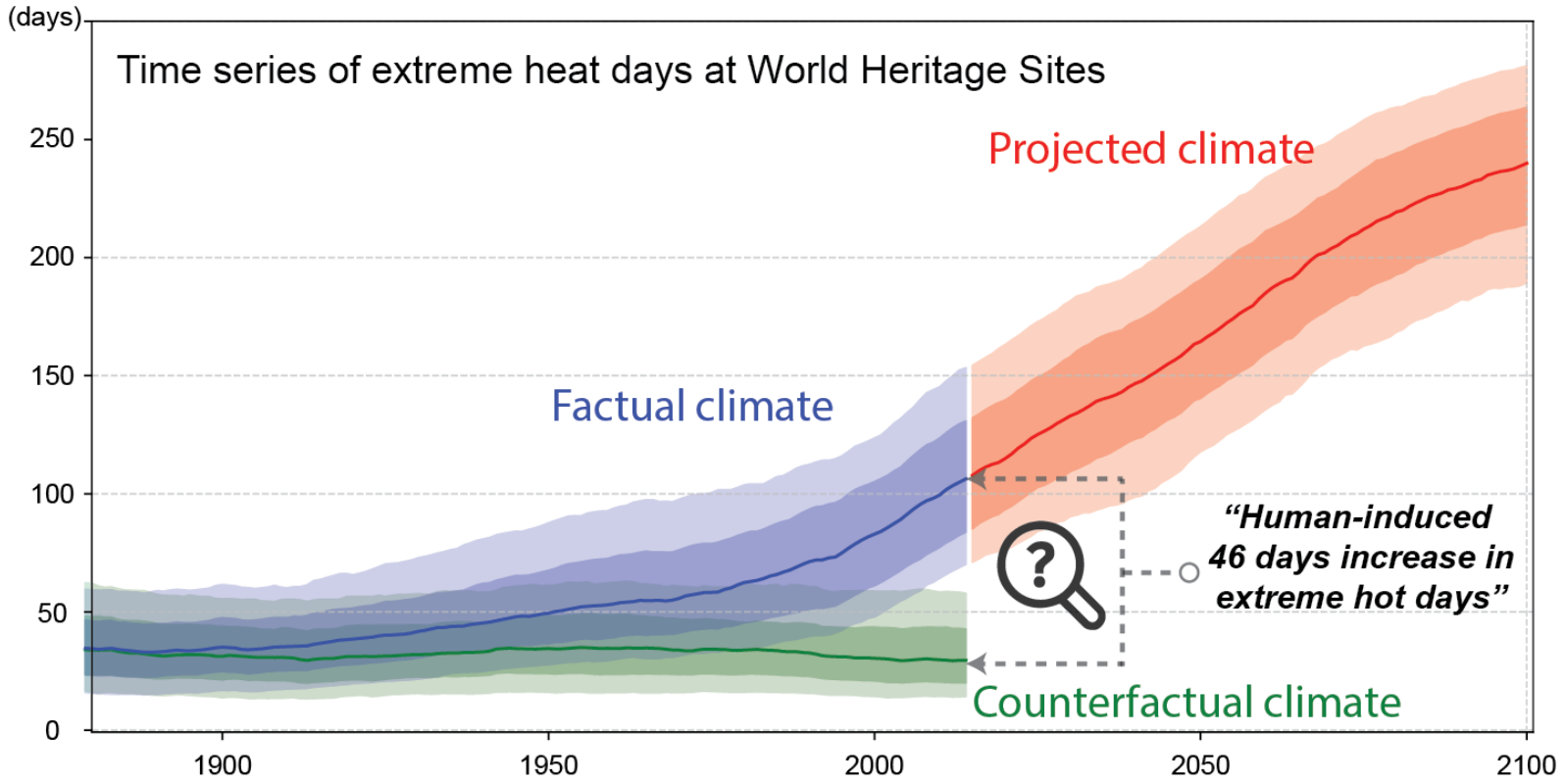
What is attribution science?



Attribution science quantifies the extent to which human-induced climate change alters the magnitude, probability, and resulting impacts of extreme weather or climate-related events.

(Stott et al., 2015; Otto, 2023)

Attribution science quantifies human influence on heritage

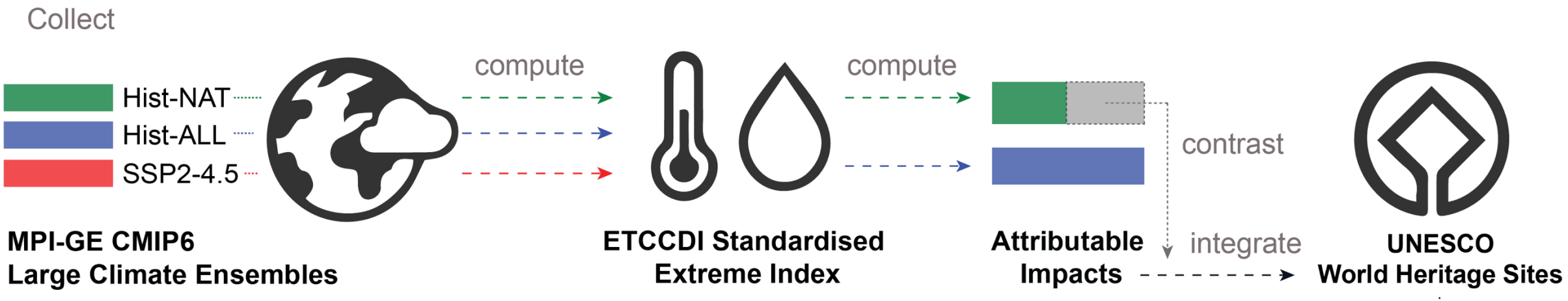


Zhao et al., 2026

Reveals causal links by comparing:

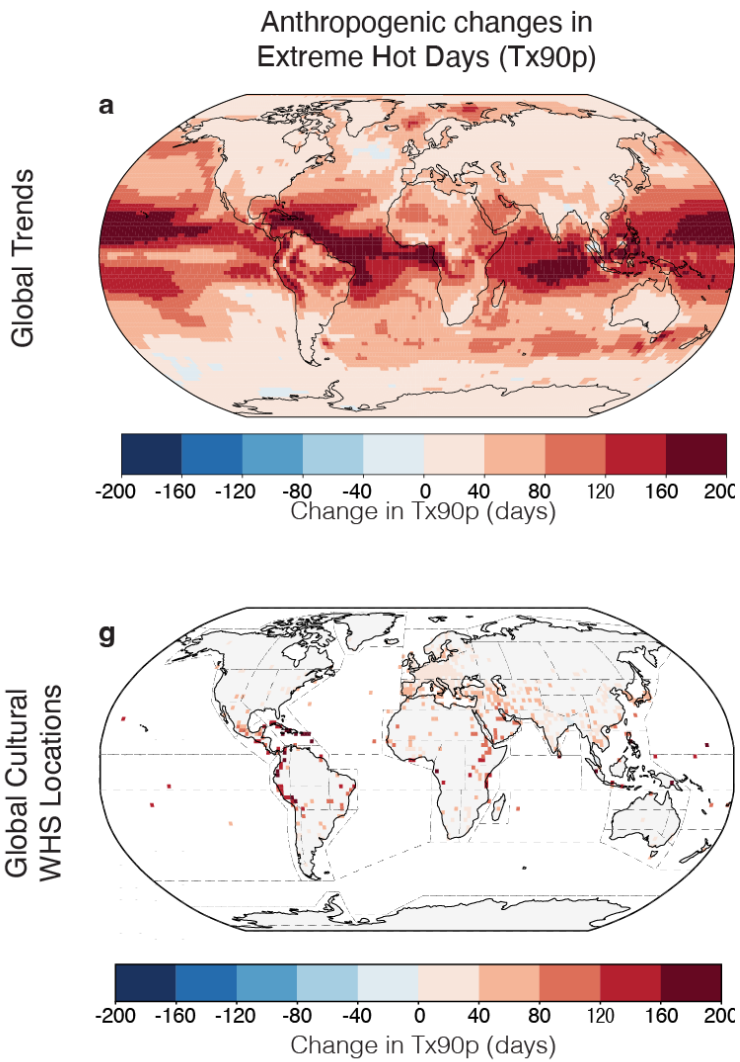
- Factual world: land-use change, greenhouse gas emissions, aerosols etc.
- Counterfactual world: only simulate volcanic and solar activities (natural-only).

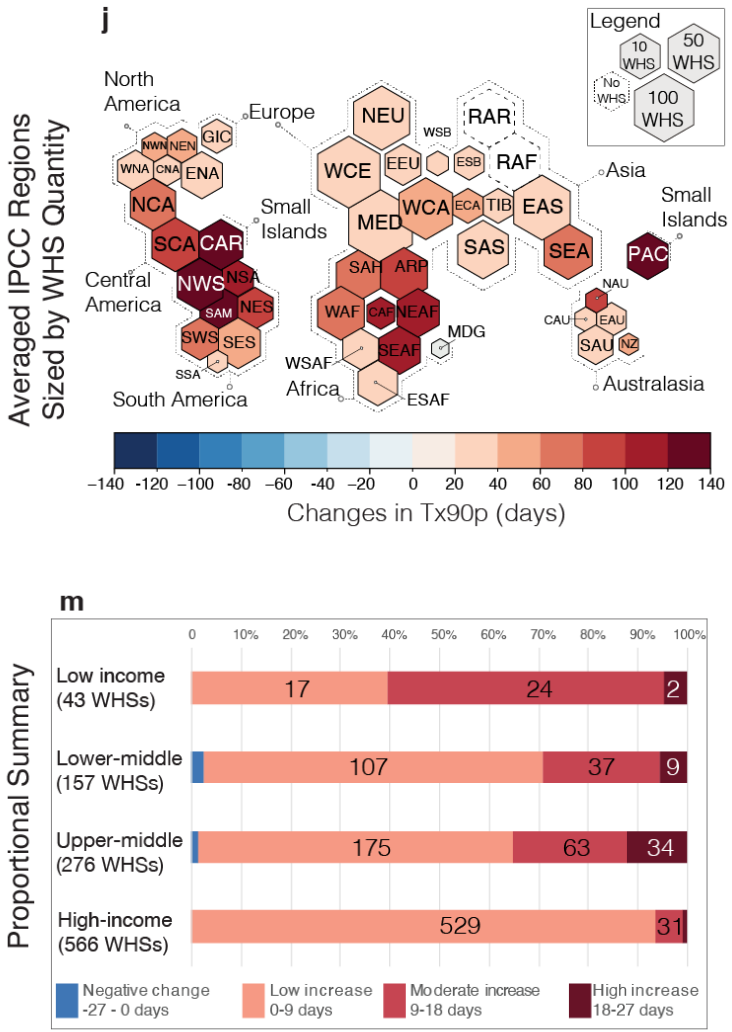
From climate simulations to attributable heritage impacts



- Collect temperature and rainfall data under factual and counterfactual scenarios.
- Calculate IPCC extreme index: e.g., Days when daily maximum temperature is greater than the 90th percentile of baseline period (1850-1900).
- Integrate World Heritage List: locations, type, year, and values.

Attribution reveals risk inequality



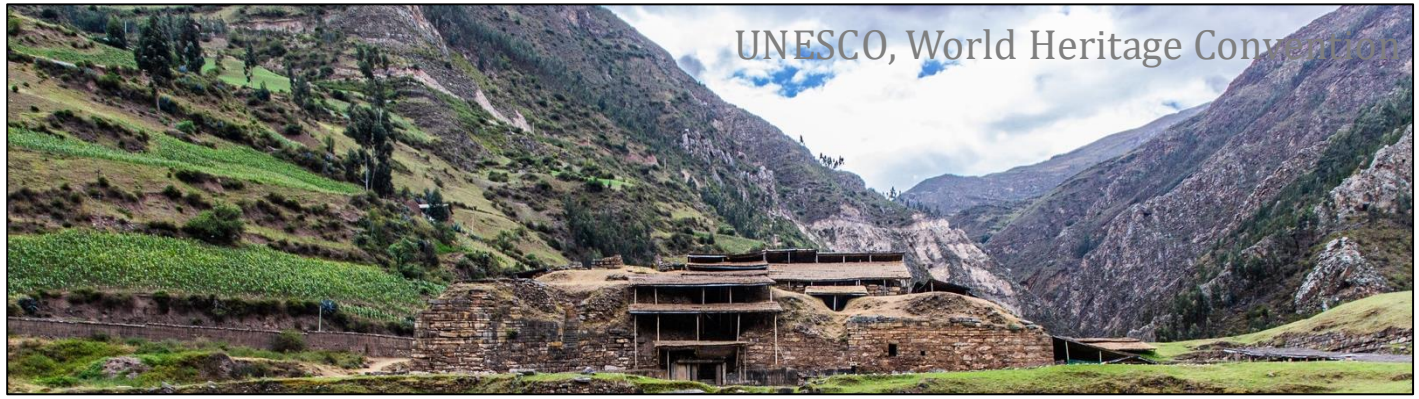


- Risk includes multiple determinants: hazard, exposure, vulnerability, and response.
- Exposure: the amount of World Heritage Sites within each reference region.
- Vulnerability: the World Bank income classification of each World Heritage State Parties.
- Low-income countries face greater attributable risks, with over half of WHSs showing moderate-to-high increases in extreme heat days.

Attribution evidence reframes ‘local’ heritage threats

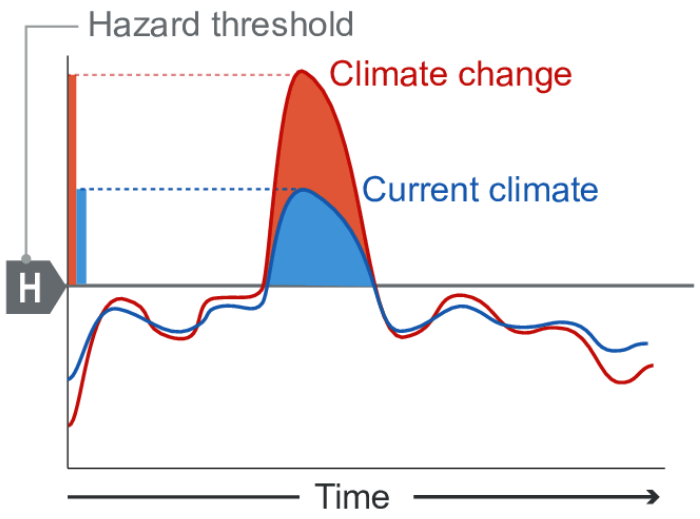
- State of Conservation (SOC) is the mandatory report system used by UNESCO to monitor the condition of World Heritage Sites under threats: climate change relevant and local factors.
- **Many ‘local’ heritage threats already contain a detectable anthropogenic climate signal.**
- Chavín Archaeological Site (Peru) has 150 extreme hot days increase, and +1.5 °C increase in daily maximum temperature that are due to climate change.

Threats category	Threats	Reports
Climate change threats	Temperature change	2
	Flooding	31
Local conditions affecting physical fabric	Temperature	7
	Water (rain/ water table)	59



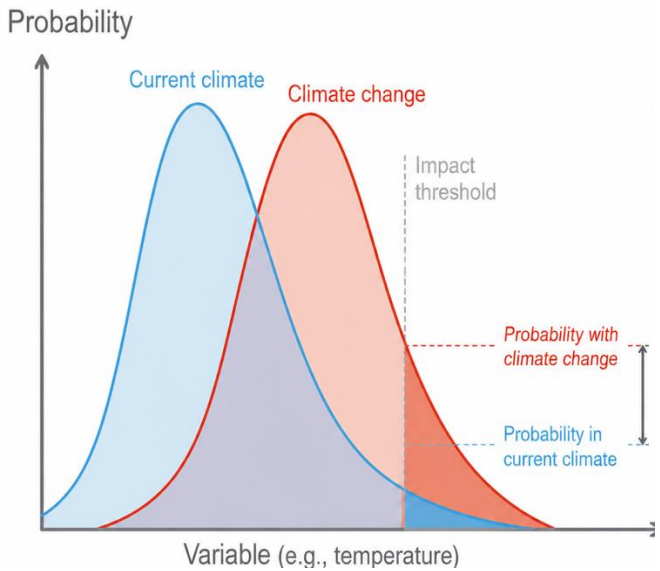
Beyond intensity: probability attribution

Intensity and Magnitude



$$\Delta I_{anthro} = I_{factual} - I_{counterfactual}$$

Probability / Likelihood

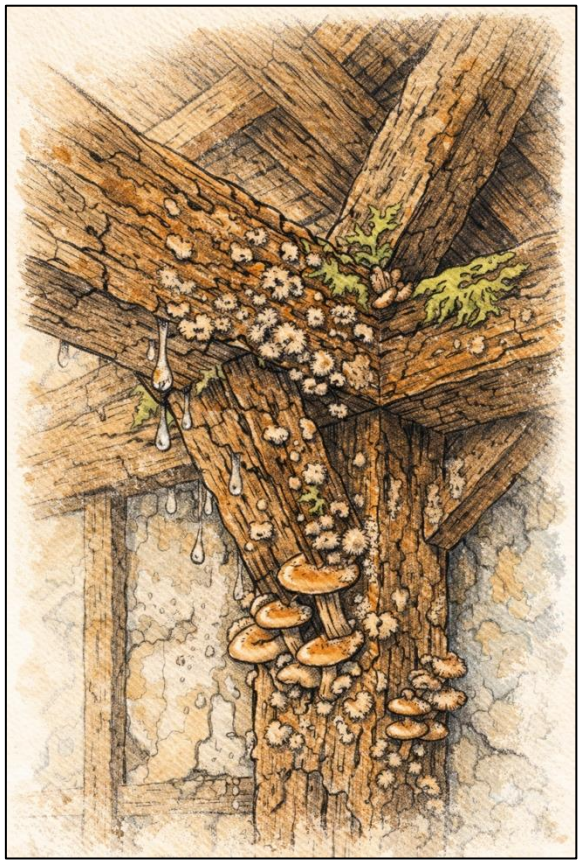


$$FAR = 1 - \frac{P_{counterfactual}}{P_{factual}}$$

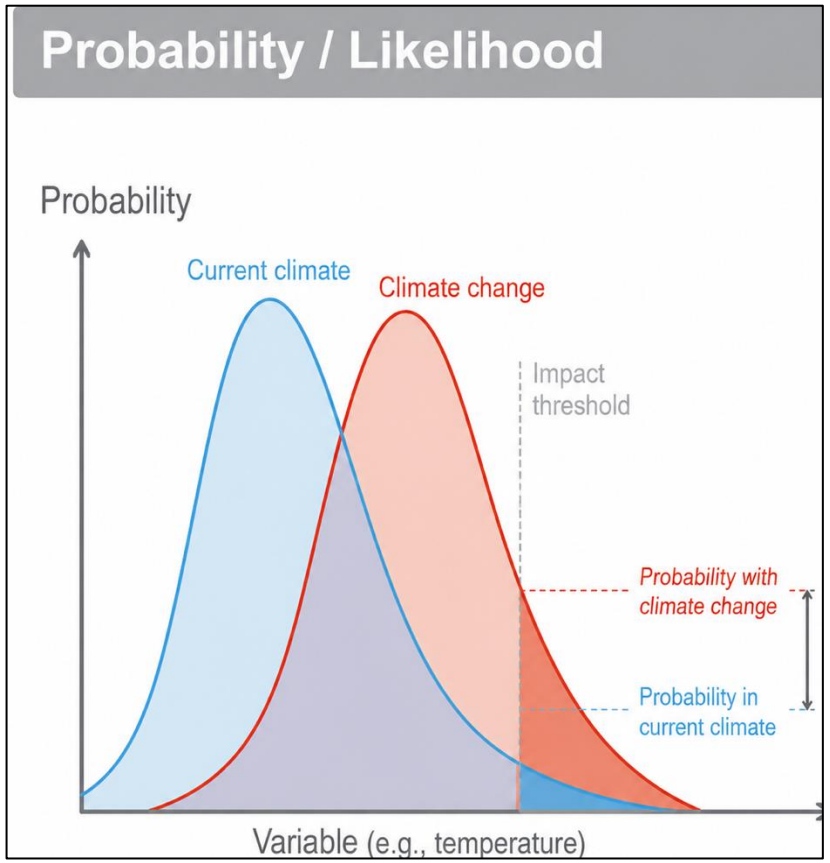
- Attribution science also evaluates how humans alter the likelihood of extreme risks, by assessing exceedance probabilities beyond a certain threshold.
- **Fraction Attributable Risk (FAR)** quantifies the proportion of an extreme event's total risk that can be directly 'blamed' on human-induced climate change (Stott et al., 2004).

Climate change increases fungal decay risks

- Scheffer Index measures the climate suitability for fungal decay in timber heritage.
- Extreme fungal impacts increased from 5% under counterfactual condition to 14% under human forcings.
- Results in a FAR of 60%, indicating that most extreme fungal decay are attributable.
- Strongest signal in WHS at Eurasia and Eastern North America.

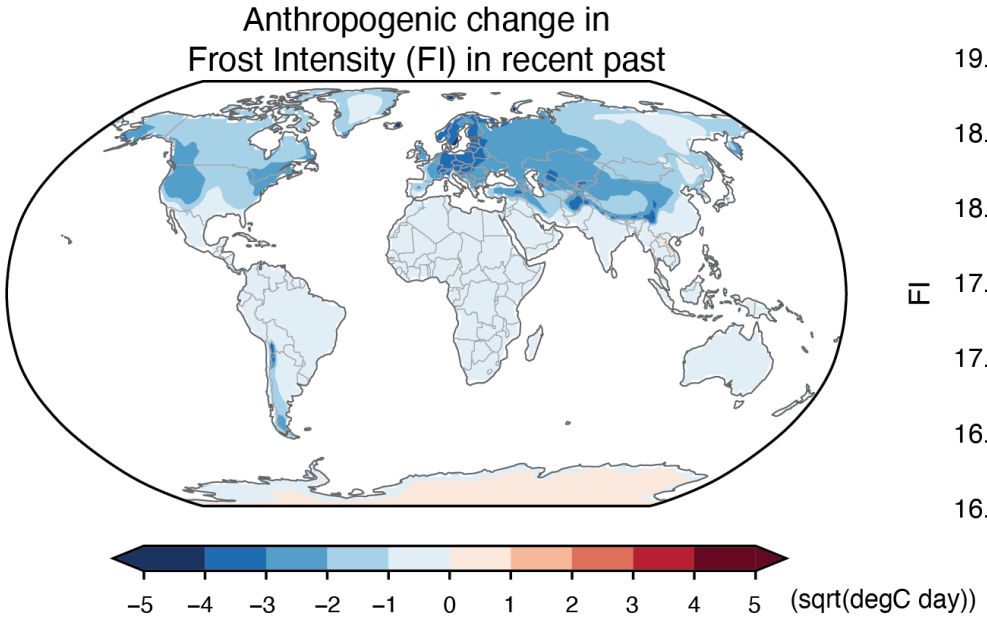


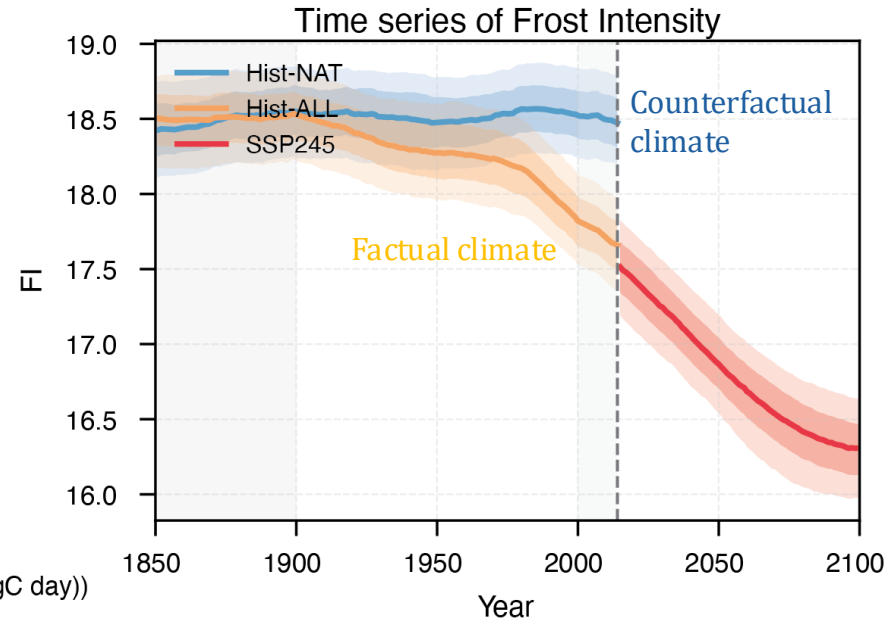
Fugal-related decay due to high temperature and humidity

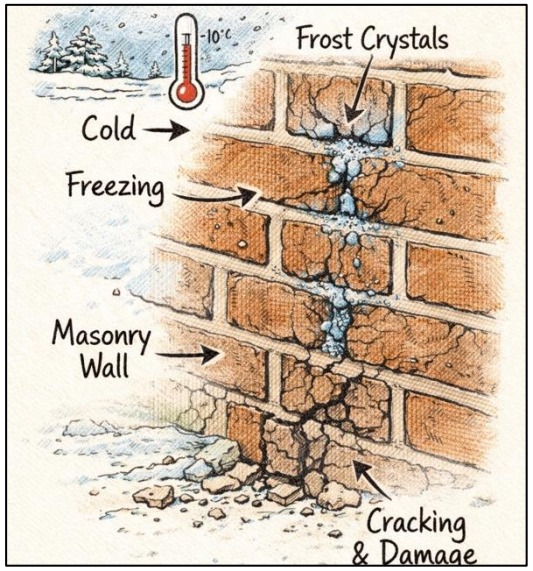


Probabilities of exceeding an extreme threshold under factual and counterfactual world

Climate change mitigates frost damage







- Frost Intensity (FI) measures the severity of freezing conditions in masonry materials.
- Humans have significantly reduced frost damage, particularly across Northern Europe and North America.
- Extreme frost risks declined sharply, with exceedance probability falling from 3.0% to 0.3% under anthropogenic climate change.

Key takeaways

- Attribution science strengthens existing evidence.
- Probability attribution adds a probability perspective.
- Heat-related risks increase globally, but risks distributed unevenly.
- Climate change also redistributes or reduces certain heritage risks.
- Attribution studies remain constrained by data uncertainty, indicators, and communication.

Let’s continue the conversation!

Message me your questions or comments in the IAIA26 app.

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