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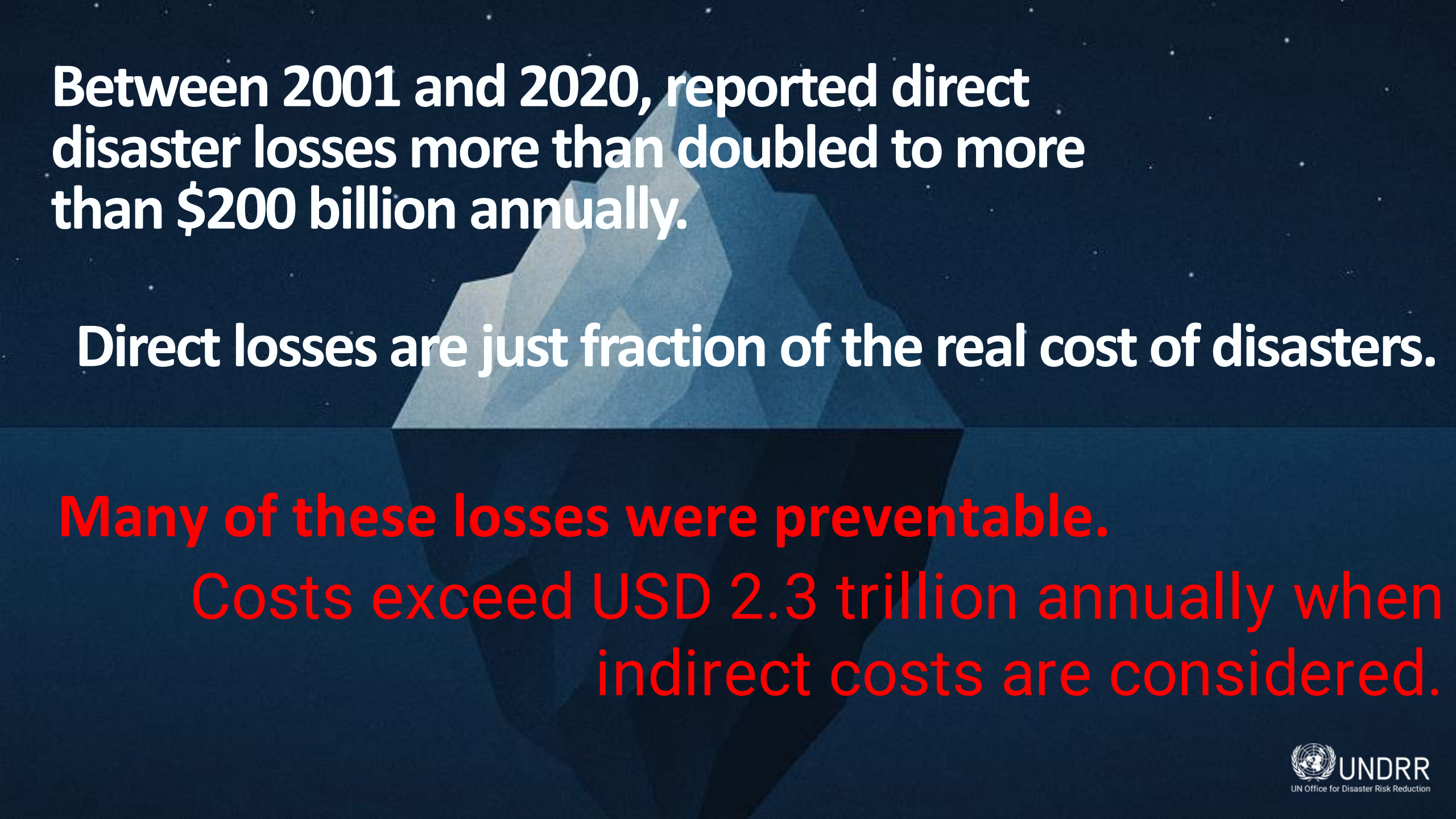
University of Strathclyde Engineering

Multi-hazard and compound events: concepts and typologies

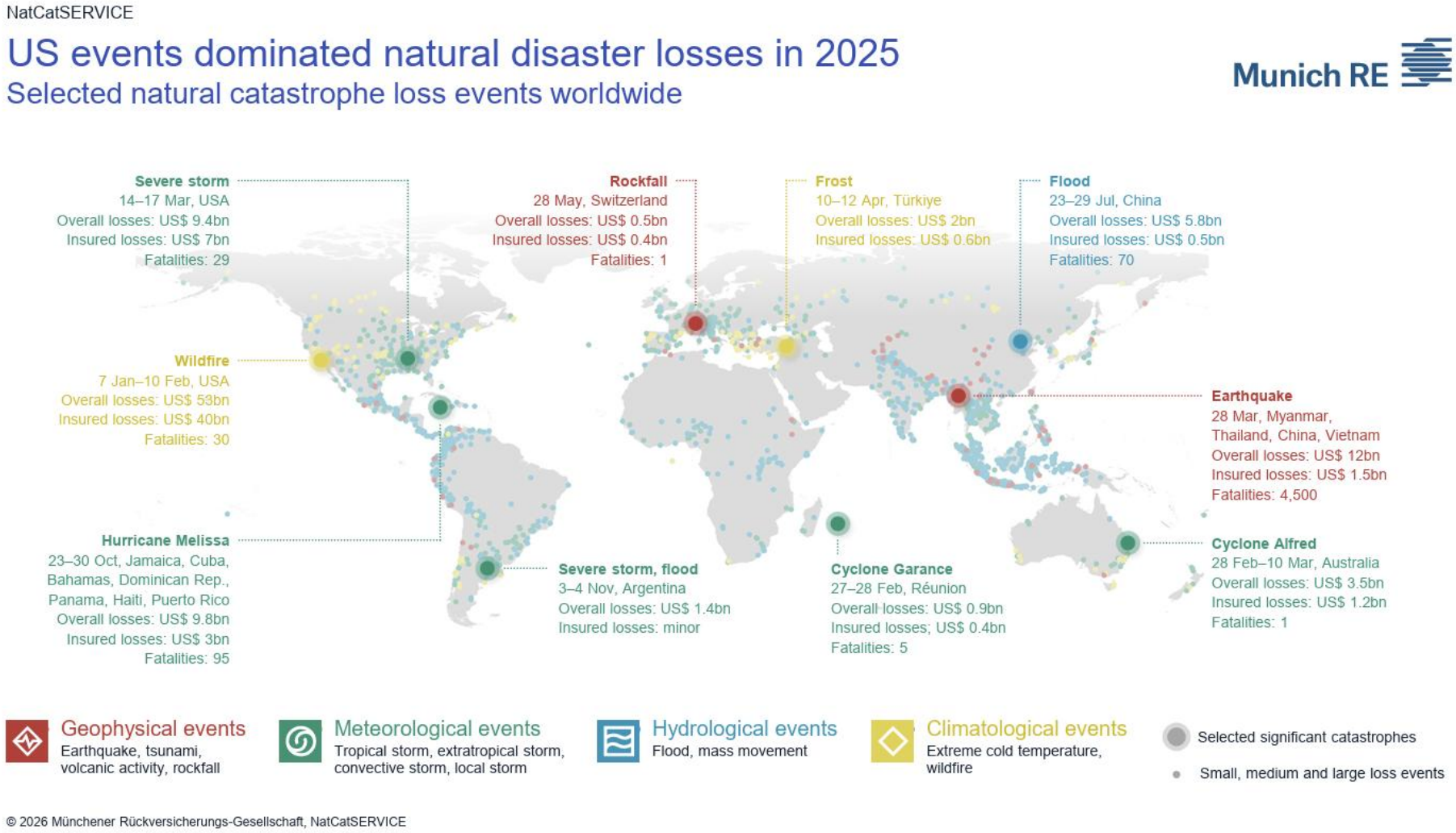
Prof Christopher J. White[1]

[1] Department of Civil and Environmental Engineering, University of Strathclyde, Glasgow, UK

EGU 2026, Vienna
EGU2026 SC2.1 Compound Events and Multi-Hazard Analytics Short Course
06 May 2026

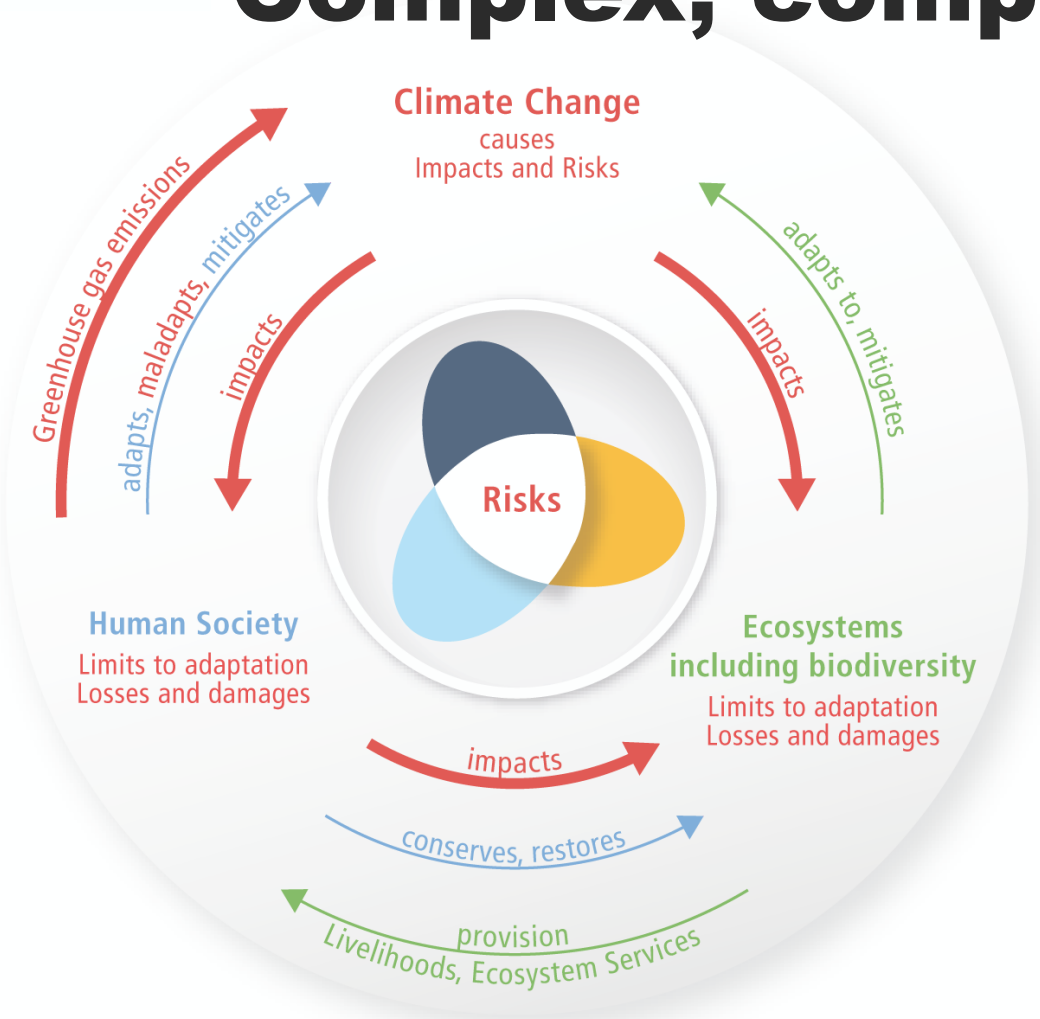

Between 2001 and 2020, reported direct disaster losses more than doubled to more than $200 billion annually.
Direct losses are just fraction of the real cost of disasters.
Many of these losses were preventable.
Costs exceed USD 2.3 trillion annually when indirect costs are considered.
UNDRR
UN Office for Disaster Risk Reduction

Single hazard event reporting



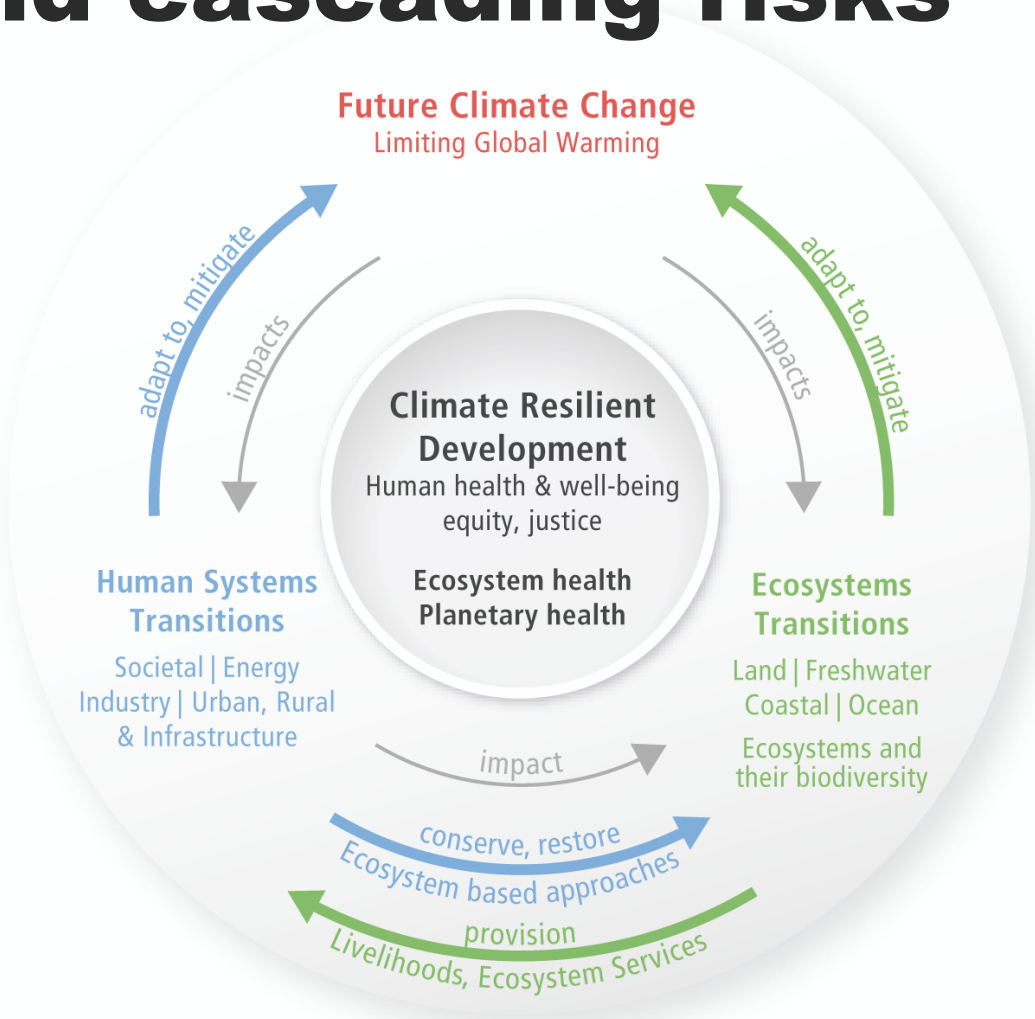
Source: https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/media-information/2026/natural-disaster-figures-2025.html

Complex, compound and cascading risks



From urgent to timely action

Governance
Finance
Knowledge and capacity
Catalysing conditions
Technologies



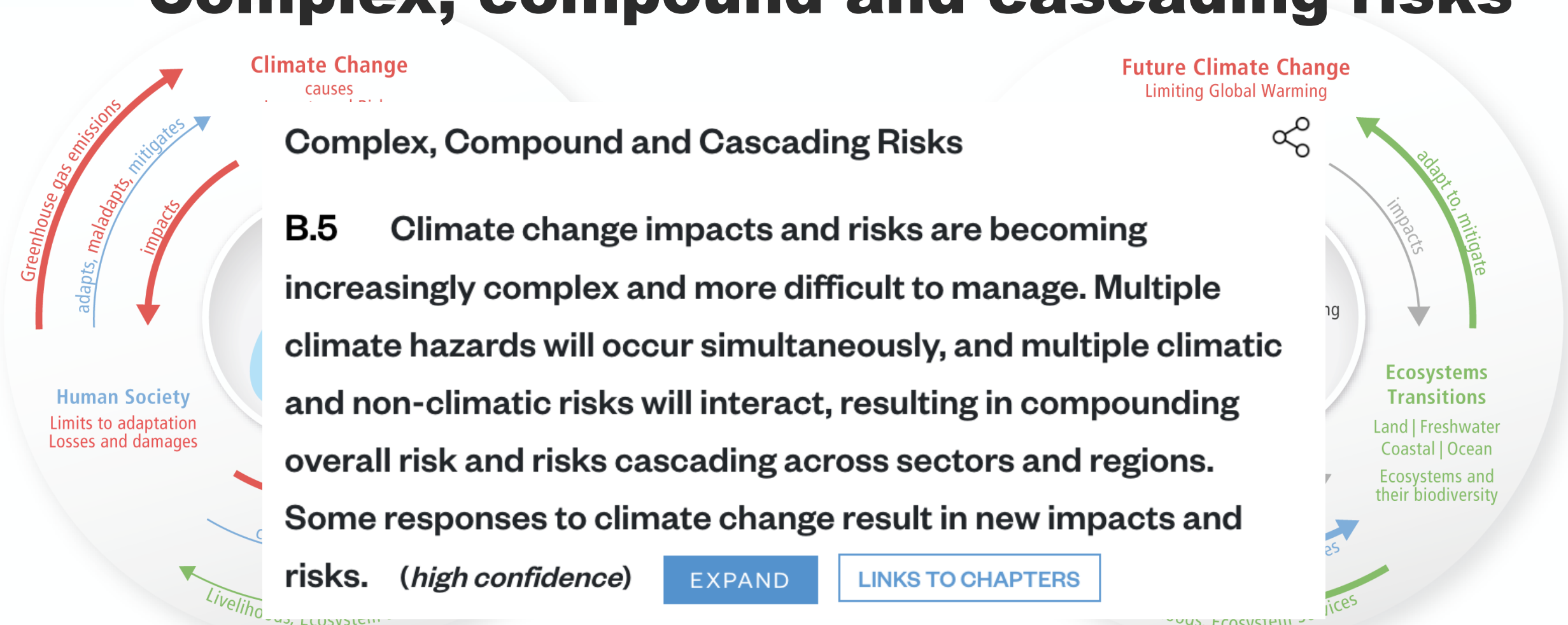
The risk propeller shows that risk emerges from the overlap of:

Climate hazard(s) | Vulnerability | Exposure

...of human systems, ecosystems and their biodiversity

Source: IPCC Sixth Assessment Report – Climate Change 2022: Impacts, Adaptation and Vulnerability – Summary for Policymakers (2022)
https://www.ipcc.ch/report/ar6/wg2/chapter/summary-for-policymakers/

Complex, compound and cascading risks



Complex, Compound and Cascading Risks

B.5 Climate change impacts and risks are becoming increasingly complex and more difficult to manage. Multiple climate hazards will occur simultaneously, and multiple climatic and non-climatic risks will interact, resulting in compounding overall risk and risks cascading across sectors and regions. Some responses to climate change result in new impacts and risks. (*high confidence*)

EXPAND LINKS TO CHAPTERS

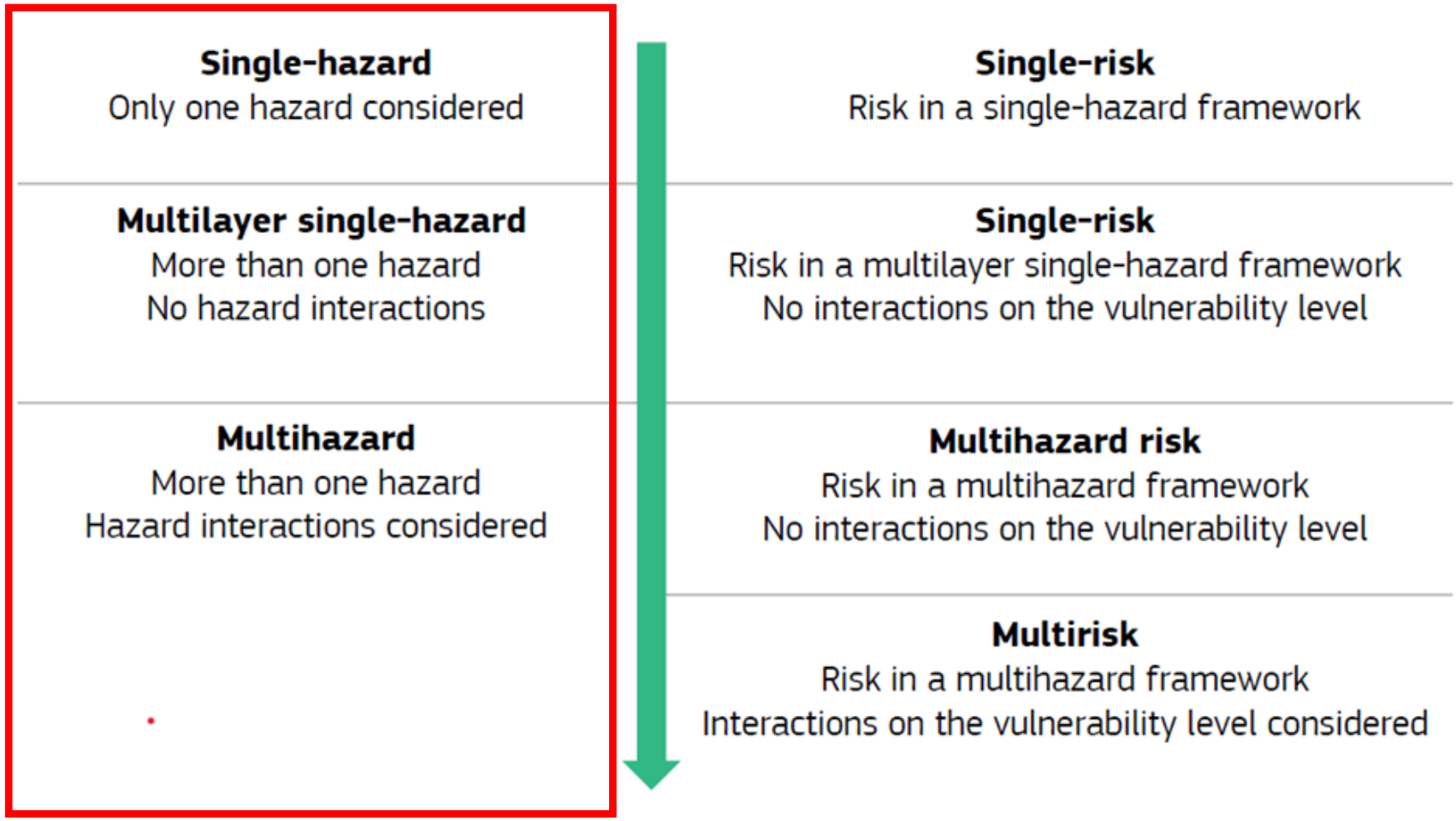
The risk propeller shows that risk emerges from the overlap of:

Climate hazard(s) Vulnerability Exposure

...of human systems, ecosystems and their biodiversity

Source: IPCC Sixth Assessment Report – Climate Change 2022: Impacts, Adaptation and Vulnerability – Summary for Policymakers (2022)
https://www.ipcc.ch/report/ar6/wg2/chapter/summary-for-policymakers/

Some definitions



Source: Zschau (2017) https://drmkc.jrc.ec.europa.eu/portals/0/Knowledge/ScienceforDRM/ch02/ch02_subch0205.pdf

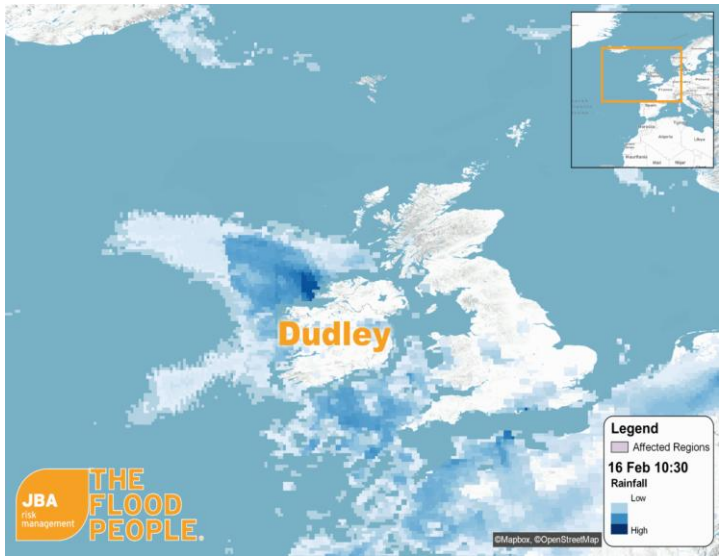
Example: UK storm sequences in 2021

Triplet of storms in NW Europe in 2021 – consecutive impacts

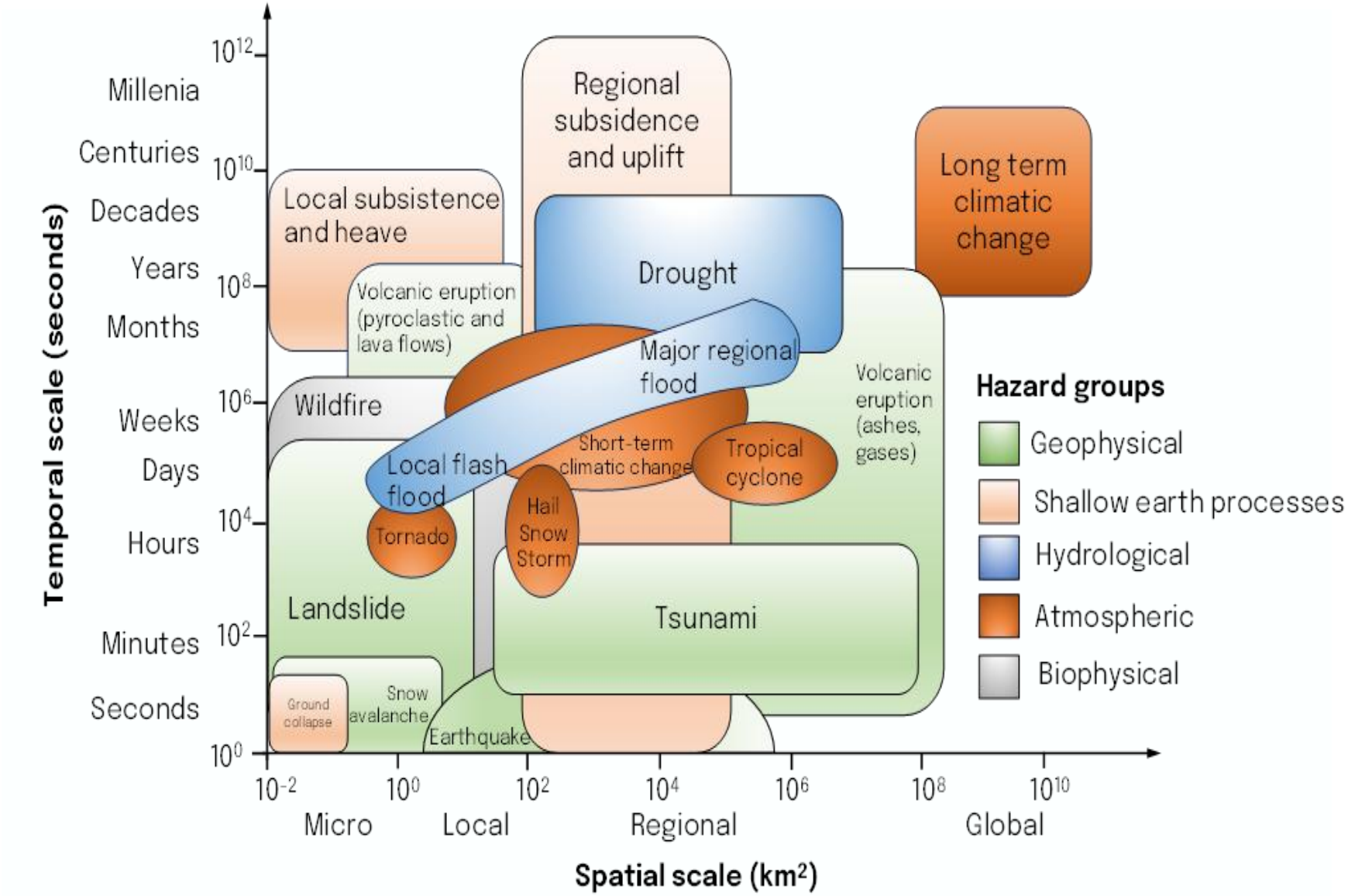
Dudley

Eunice

Franklin



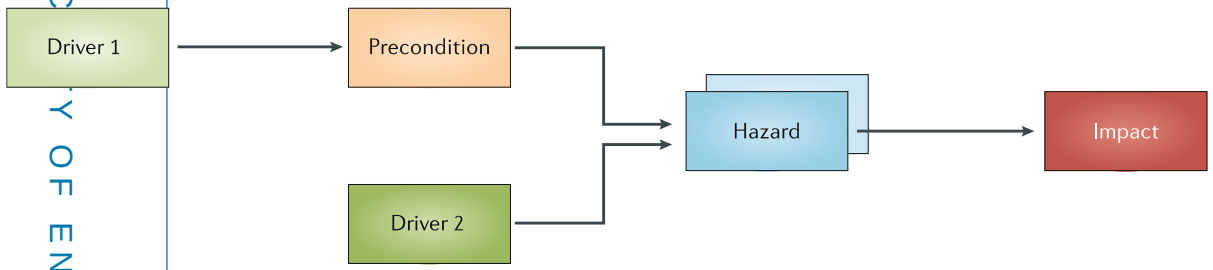
Challenges of multi-hazards



Source: Gill & Malamud (2014) https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2013RG000445

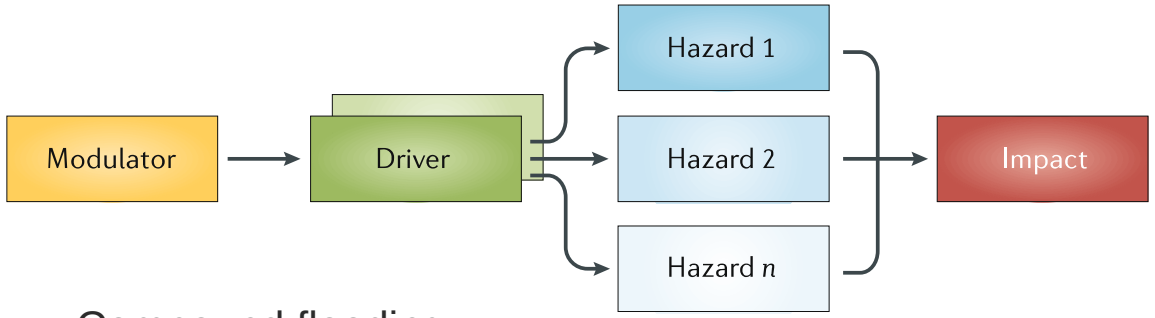
Compound / multi-hazard events typology

Preconditioned



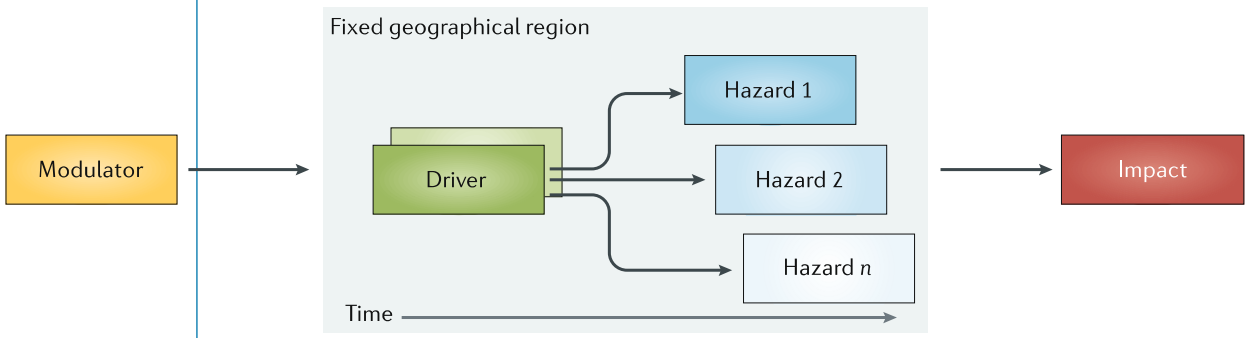
- False spring
- Rain-on-snow flood

Multivariate



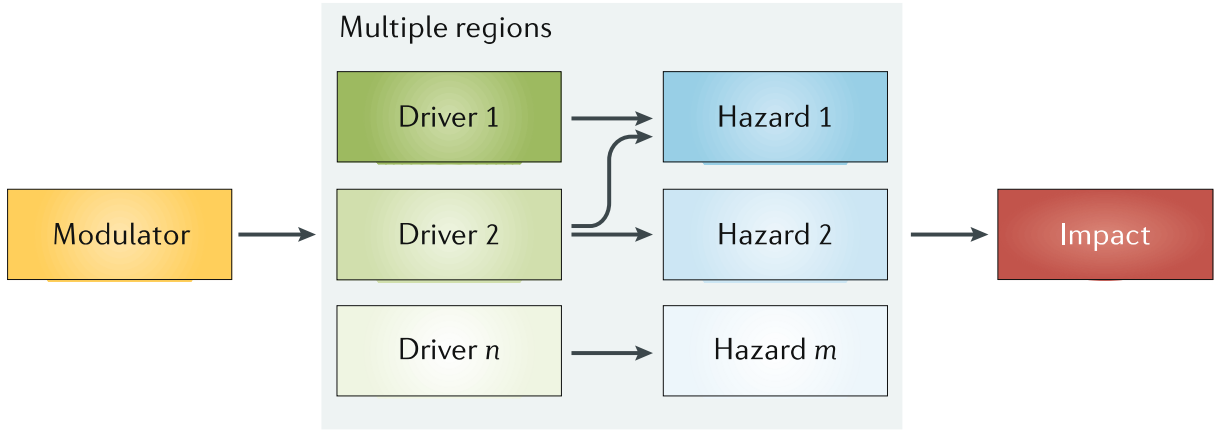
- Compound flooding
- Concurrent drought & heat
- Concurrent wind & precipitation extremes

Temporally compounding



- Sequence of storms/heavy precipitation events

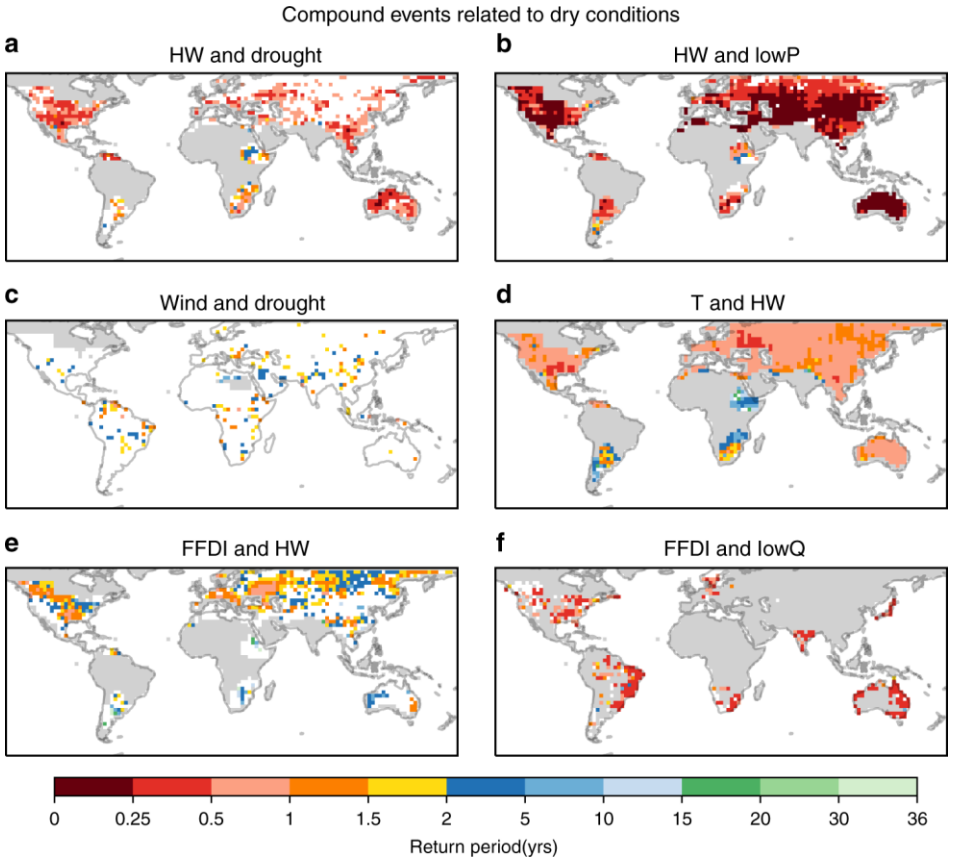
Spatially compounding

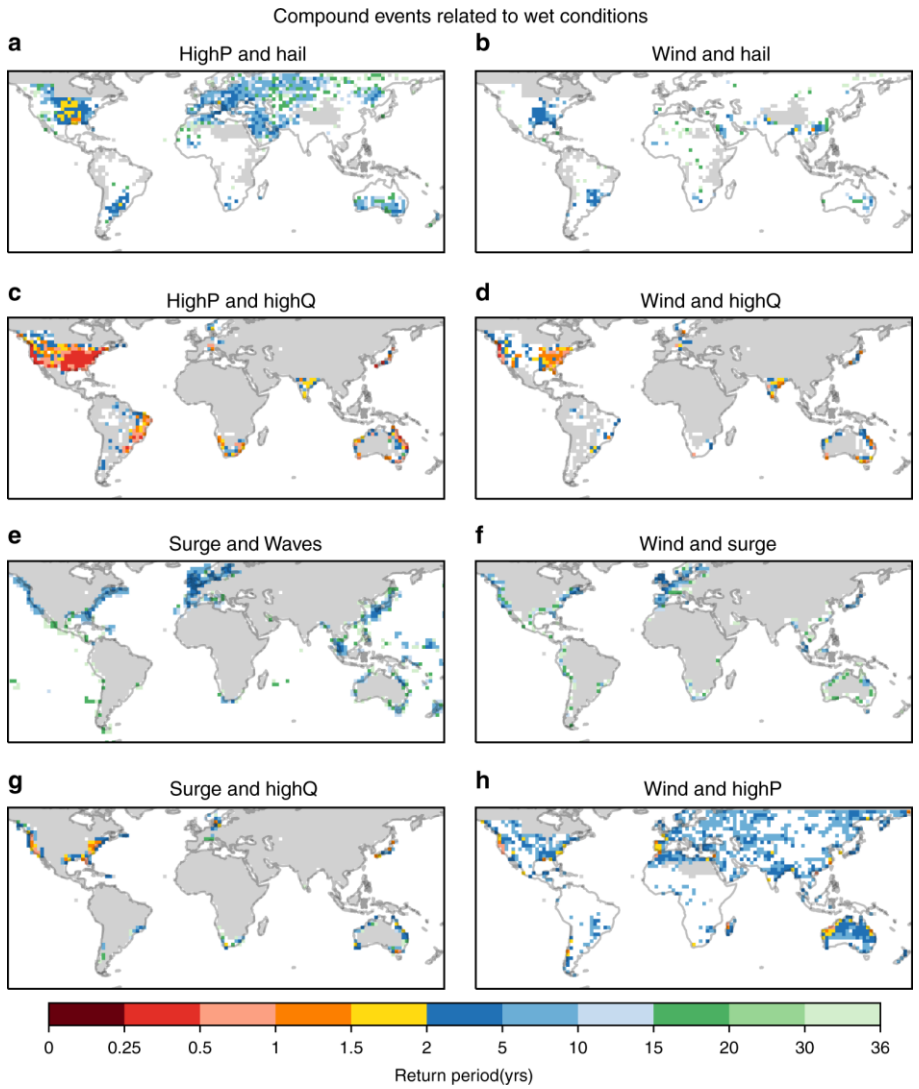


- Global crop failure

Source: Zscheischler et al. (2020) https://www.nature.com/articles/s43017-020-0060-z

Global hotspots





Source: Ridder et al. (2020) https://www.nature.com/articles/s41467-020-19639-3?fromPaywallRec=false

Annual event ‘chronicles’

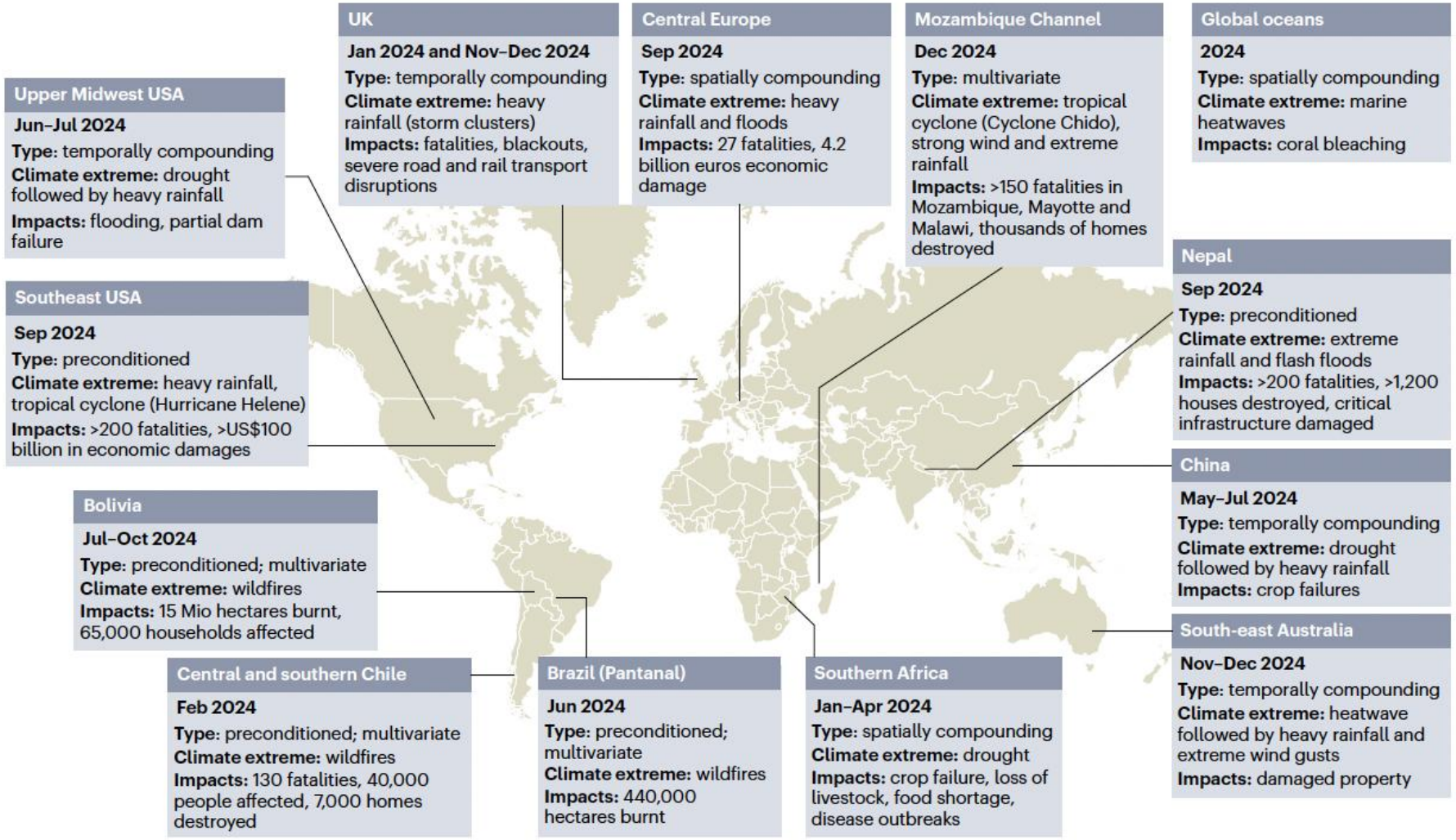
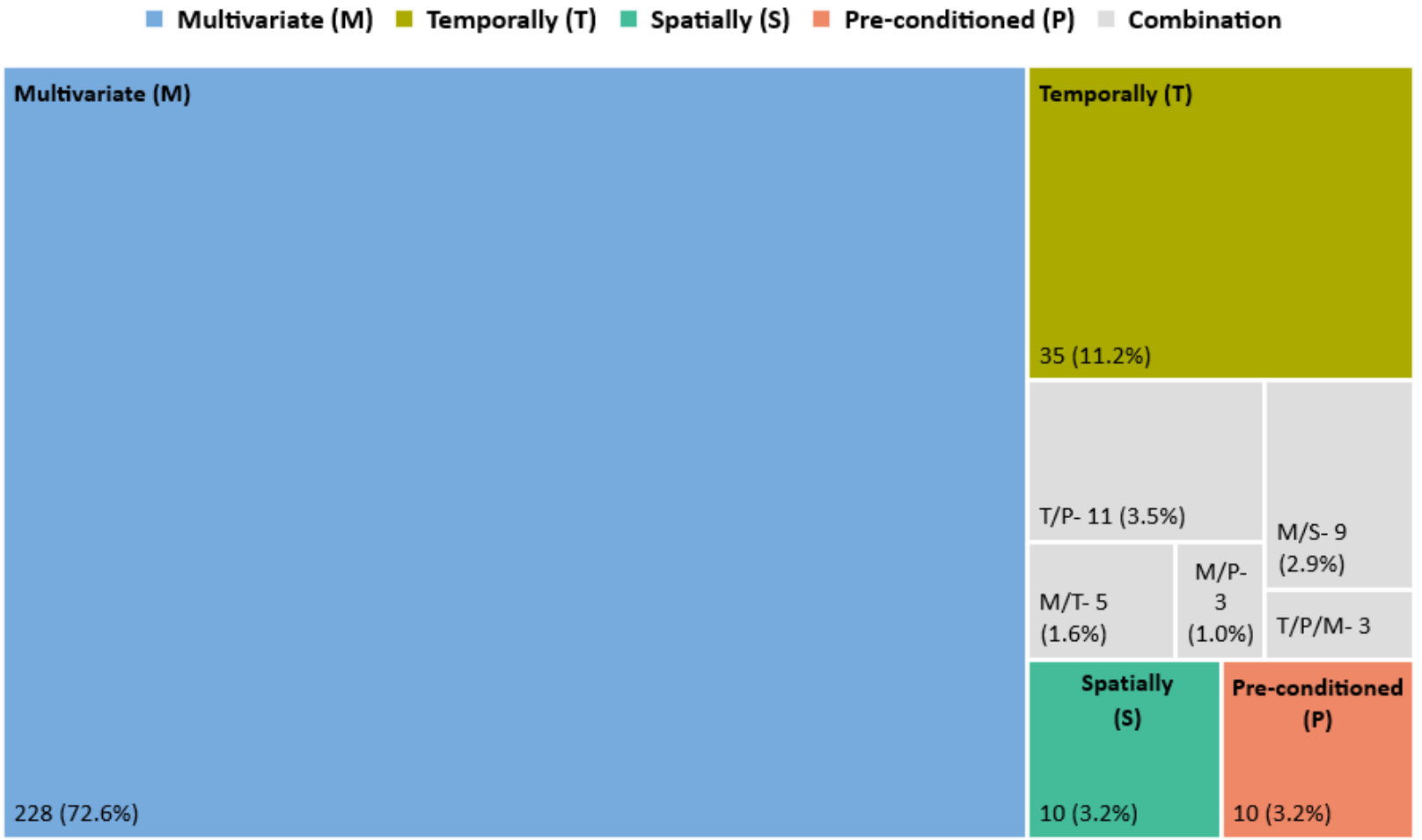


Fig. 1 | Compound events in 2024. Select examples of spatially compounding, temporally compounding, and preconditioned or multivariate compound events that occurred in 2024.

Source: Zscheischler et al. (2025) https://www.nature.com/articles/s43017-025-00657-y

Multivariate events dominate the literature



Compound events per typology - total 314.

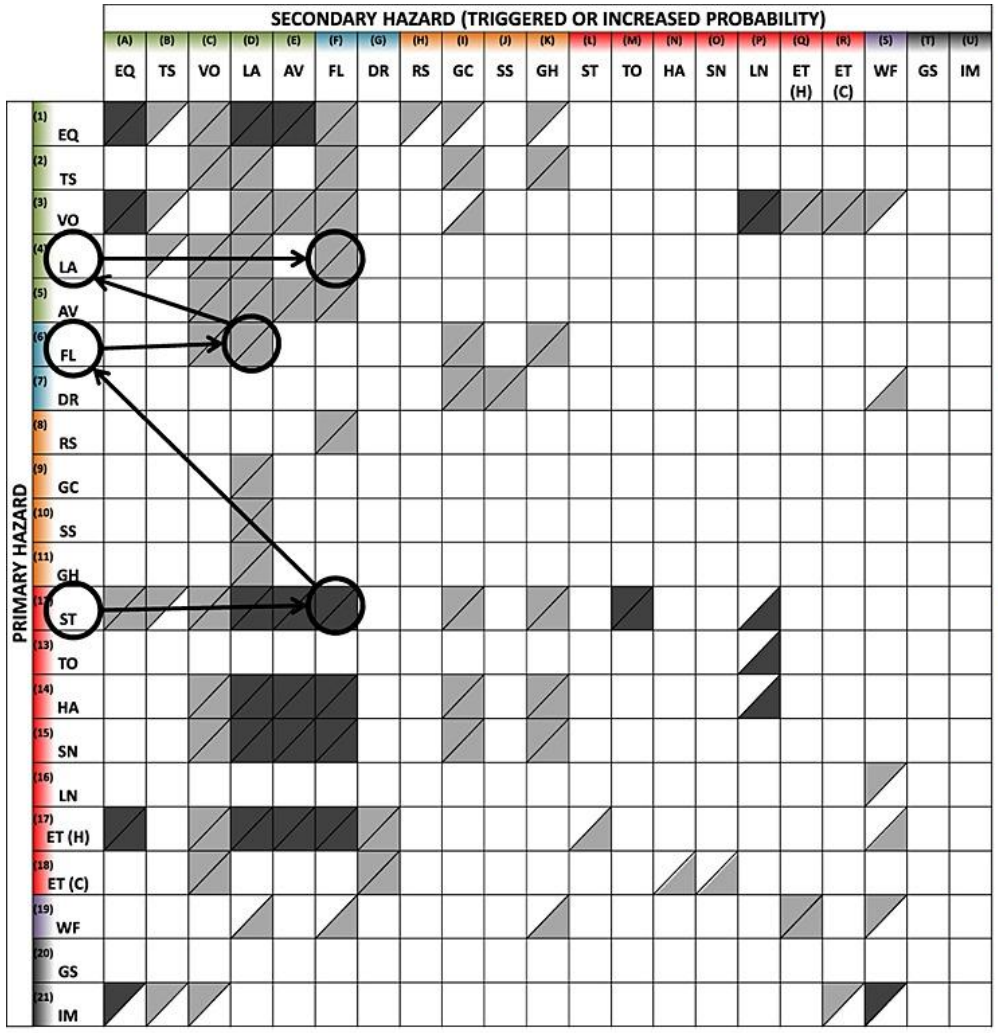
Source: Brett et al. (2025) https://nhess.copernicus.org/articles/25/2591/2025/nhess-25-2591-2025.html

Quantifying the interactions

Modelling interconnected hazards: creating a network of interacting hazards.

Primary natural hazards on the vertical axis and secondary hazards on the horizontal axis.

In this example, a storm event (ST) triggers flooding (FL), which then triggers landslides (LA).



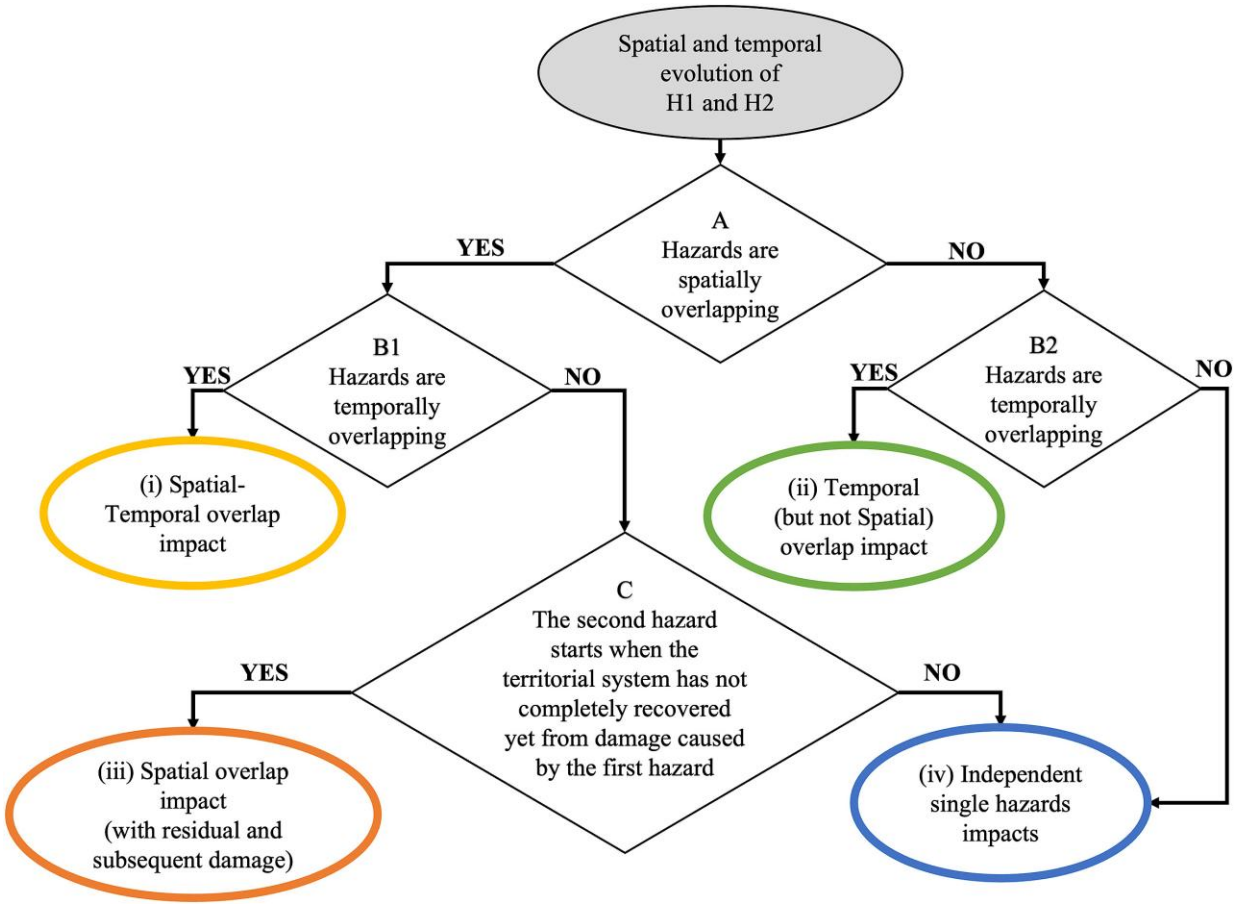
KEY		
HAZARD GROUP	HAZARD	CODE
GEOPHYSICAL	Earthquake	EQ
	Tsunami	TS
	Volcanic Eruption	VO
	Landslide	LA
	Snow Avalanche	AV
HYDROLOGICAL	Flood	FL
	Drought	DR
SHALLOW EARTH PROCESSES	Regional Subsidence	RS
	Ground Collapse	GC
	Soil (Local) Subsidence	SS
	Ground Heave	GH
ATMOSPHERIC	Storm	ST
	Tornado	TO
	Hailstorm	HA
	Snowstorm	SN
	Lightning	LN
	Extreme Temperature (Hot)	ET (H)
	Extreme Temperature (Cold)	ET (C)
BIOPHYSICAL	Wildfires	WF
SPACE	Geomagnetic Storm	GS
	Impact Events	IM

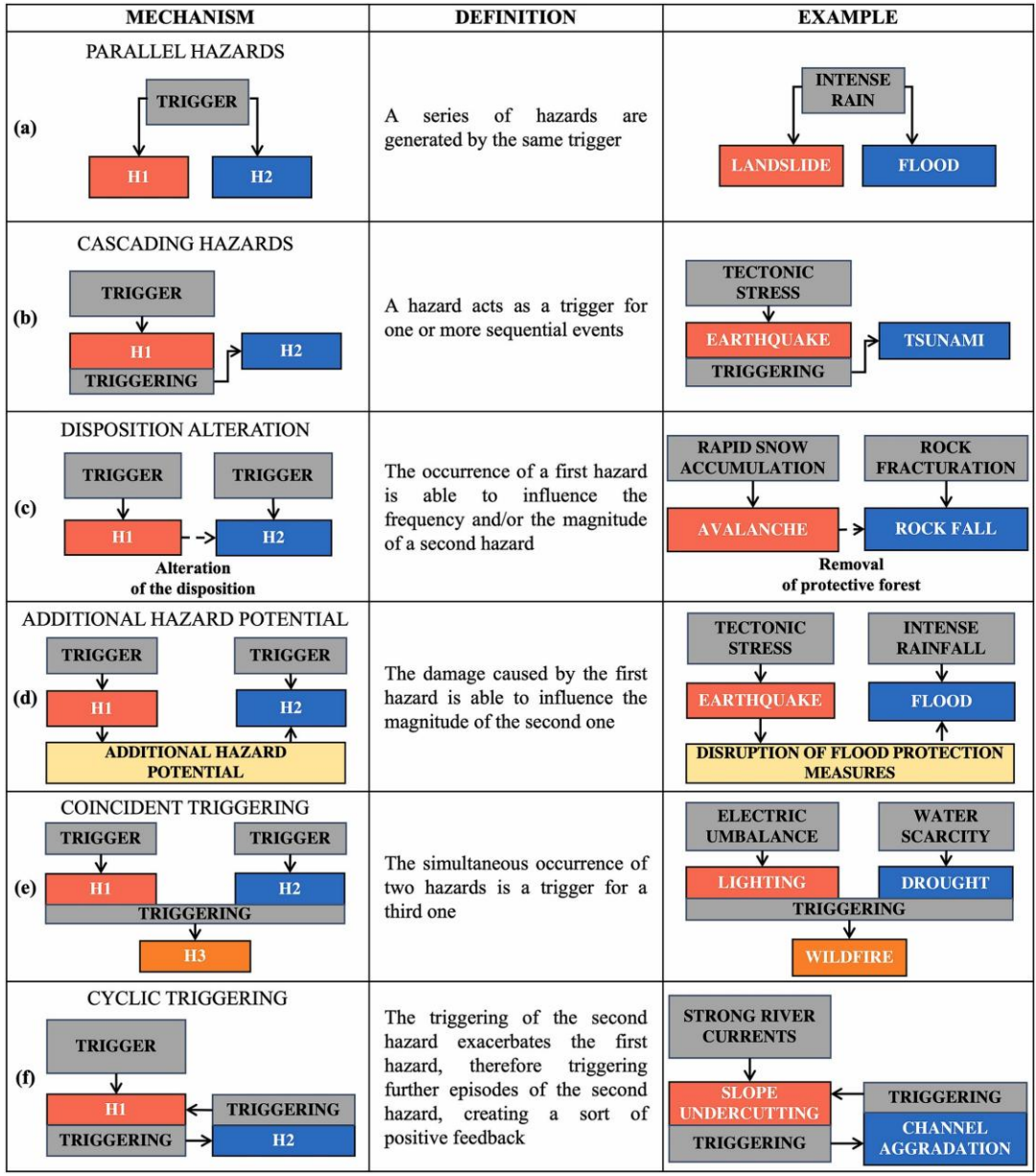
COLOUR CODE	NATURE OF SECONDARY HAZARD (FOLLOWING *ONE* OCCURRENCE OF PRIMARY HAZARD)
	Potential for a small number of hazard events (individual or a few occurrences)
	Potential for a large number of hazard events (multiple occurrences)

SYMBOL	EXPLANATION
	Hazard Triggers Secondary Hazard
	Hazard Increases Probability of Secondary Hazard
	Hazard Both Triggers and Increases the Probability of Secondary Hazard

Source: Gill & Malamud (2014) https://doi.org/10.1002/2013RG000445

Quantifying the impacts





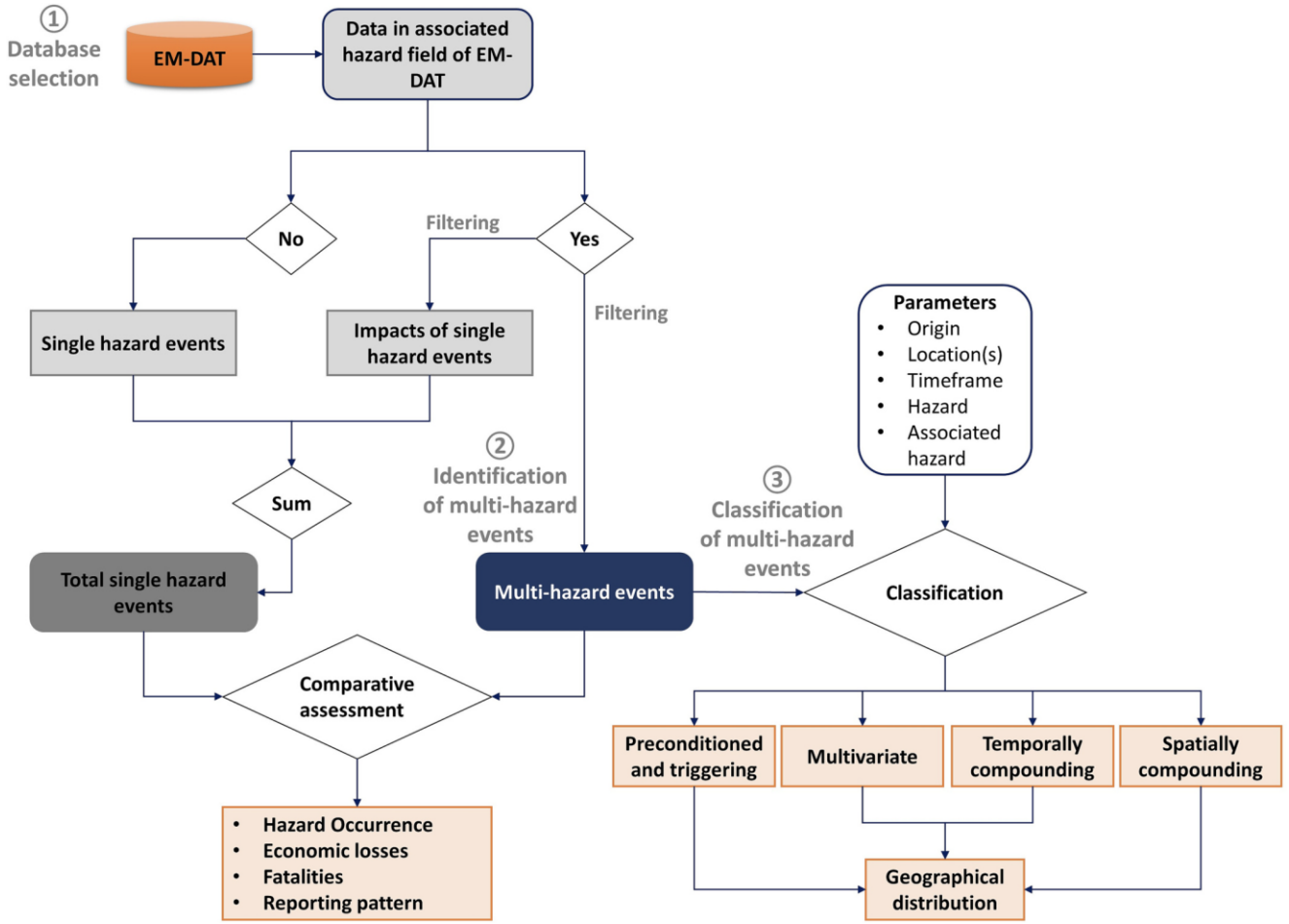
Mapping the mechanisms between interconnected hazards.

Source: De Angeli et al. (2022) https://www.sciencedirect.com/science/article/pii/S2212420922000486?via%3Dihub

Quantifying multi-hazard occurrences

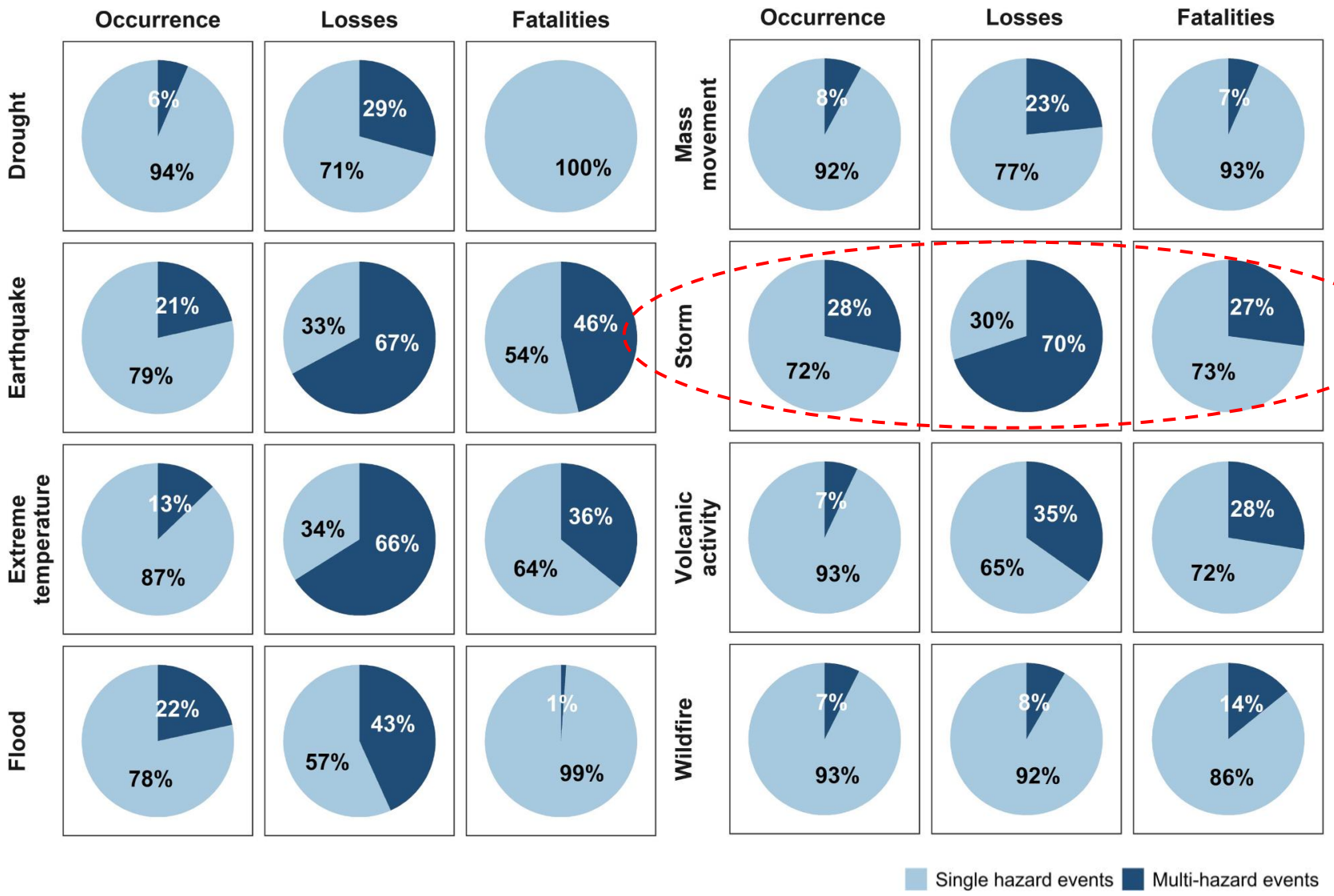
Study objectives:

- Present a method to attribute the complex nature of natural hazard interactions using observations
- Identify multi-hazard events during the past 123 years (1900–2023) using the EM-DAT global disaster database leveraging the ‘associated hazard’ category
- Reclassify hazards into four categories: preconditioned/triggering, multivariate, temporally compounding, and spatially compounding multi-hazard events
- Explore proportional and directional relationships between combinations of primary and associated hazard pairs



Source: Lee et al. (2023) https://doi.org/10.1016/j.scitotenv.2023.169120

Quantifying multi-hazard occurrences



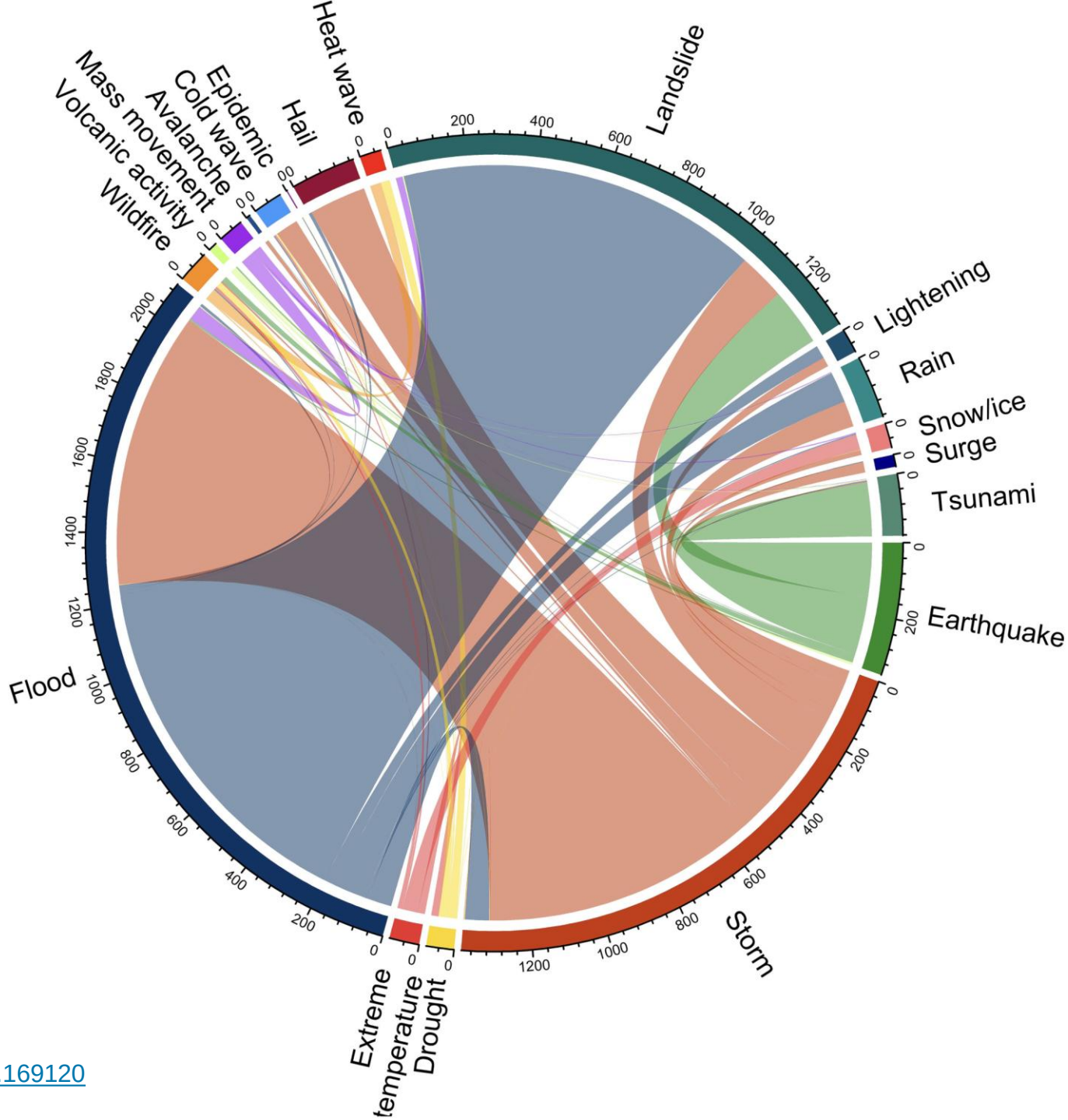
Approximately 19% of the 16,535 disasters in EM-DAT can be classified as multi-hazard events, but these events are disproportionately responsible for nearly 59% of the estimated global economic losses.

Source: Lee et al. (2024) https://doi.org/10.1016/j.scitotenv.2023.169120; UNDRR GAR (2025) https://www.undrr.org/gar/gar2025

Global multi-hazard pairings

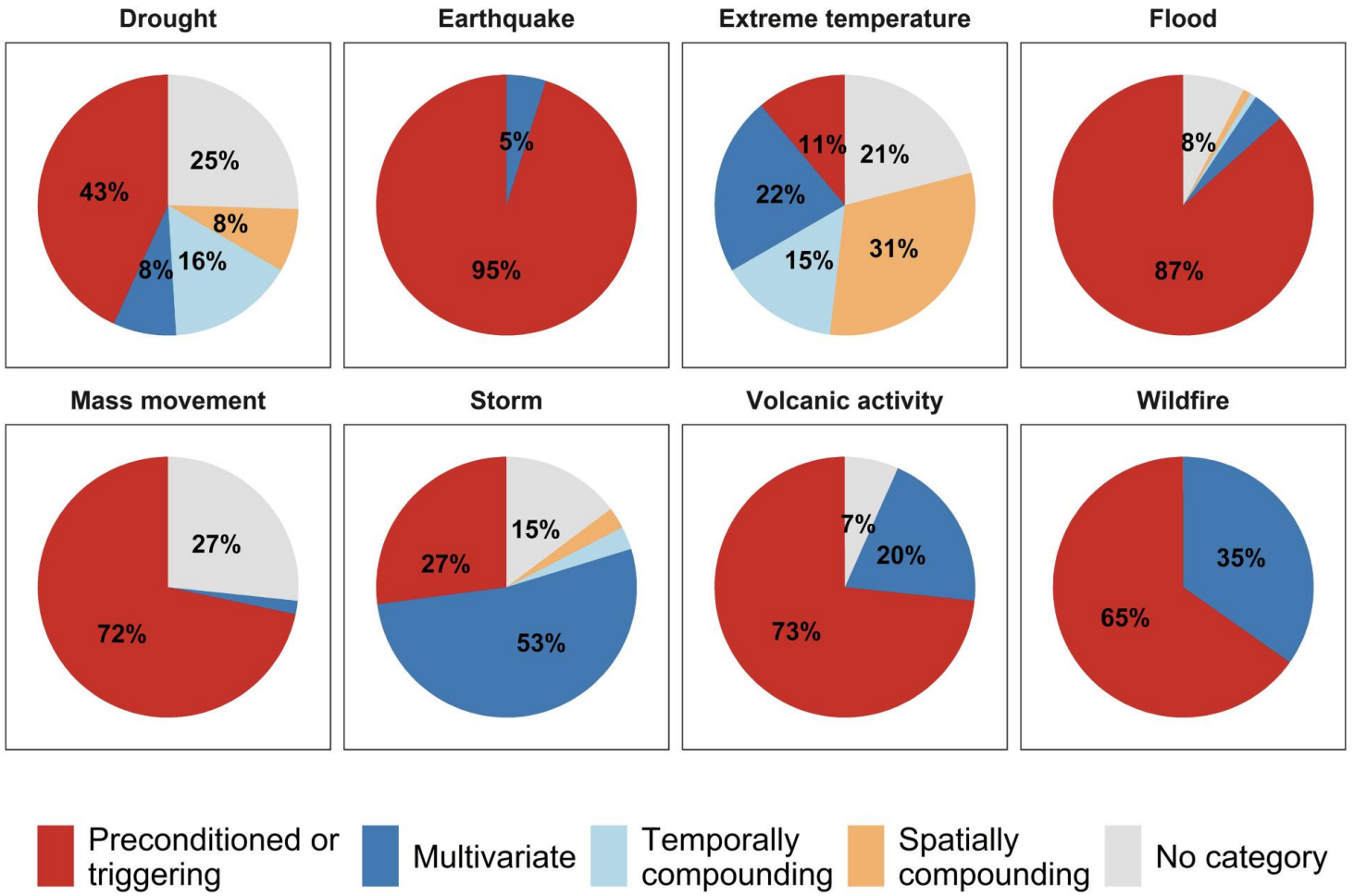
Multi-hazard Circos plot illustrating proportional and directional relationships between different combinations of eight primary hazard and seventeen associated hazard pairs using EM-DAT (1900-2023).

Each coloured arc segment corresponds to a specific hazard type. The connections between coloured segments denote hazard interactions, with line thickness indicating the relative frequency of multi-hazard occurrences.



Source: Lee et al. (2024) https://doi.org/10.1016/j.scitotenv.2023.169120

Global multi-hazard pairings



Distribution of multi-hazard events using EM-DAT (1900-2023) across the four categories: preconditioned/triggering, multivariate, temporally compounding, and spatially compounding.

Source: Lee et al. (2023) https://doi.org/10.1016/j.scitotenv.2023.169120

Compound cold-dry/wet

International Journal of Climatology | RMetS

RESEARCH ARTICLE | Open Access

Characterising Cold-Dry and Cold-Wet Compound Events in the United Kingdom

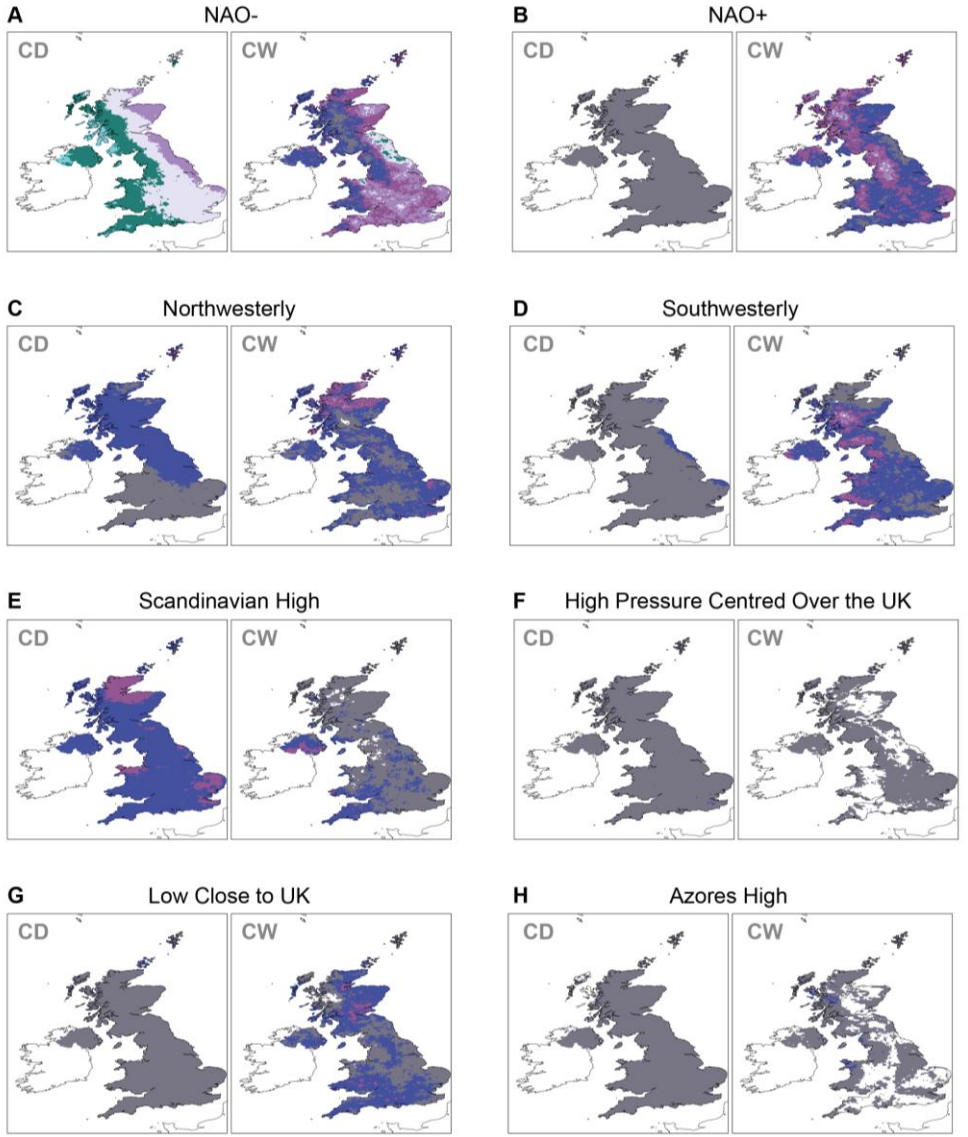
Kanzis L. Mattu, Christopher J. White, Hannah Bloomfield, Joanne Robbins

First published: 05 April 2025 | https://doi.org/10.1002/joc.8859

- **Distinct spatial patterns of cold-dry (CD) vs. cold-wet (CW) events**
  CD events (cold-dry) occur up to ~14 days per winter in the western UK region, but only about 4-8 days in the east; by contrast CW events (cold-wet) show the opposite pattern (0-1 days in the west vs 2-3 days in the east).

- **Different atmospheric drivers for CD vs. CW events**
  CD events are largely associated with anticyclonic weather patterns and a negative phase of the North Atlantic Oscillation (NAO), while CW events tend to be driven by cyclonic weather patterns.

- **Implications for impact-based forecasting and regional planning**
  Using a *location-specific percentile approach* paired with analysis of weather-pattern drivers offers a useful tool for medium-range forecasting of compound cold events (both CD and CW), which is valuable for sectors like health, transport and energy.



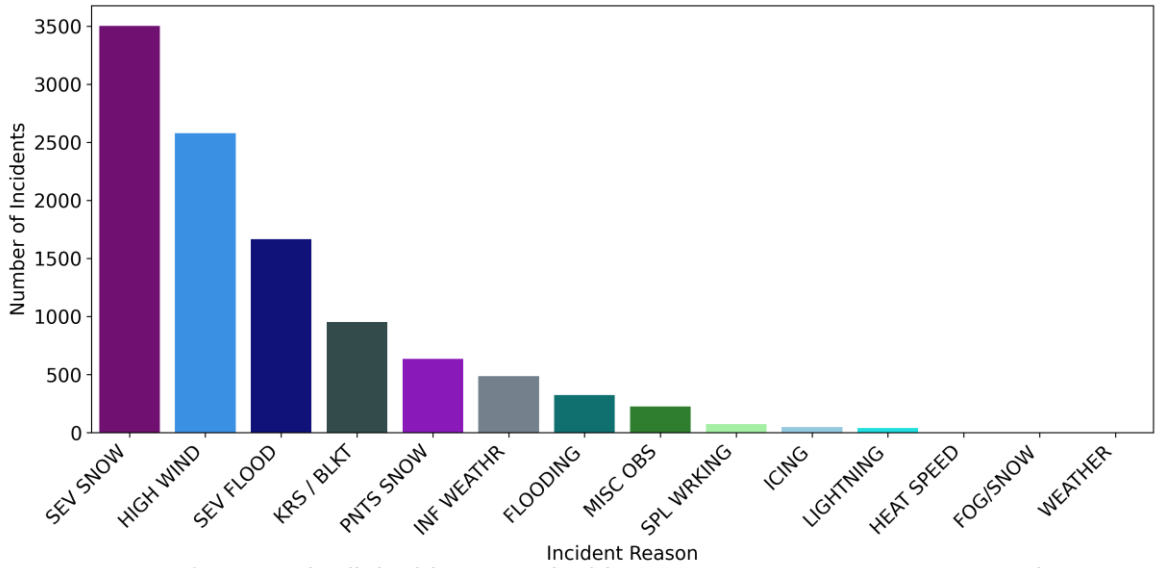
Percentage of CD and CW day occurrence under eight weather regimes. (A) NAO−, (B) NAO+, (C) Northwesterly, (D) Southwesterly, (E) Scandinavian High, (F) High Pressure Centred Over the UK, (G) Low Close to UK, (H) Azores High.

Compound cold-dry/wet impacts

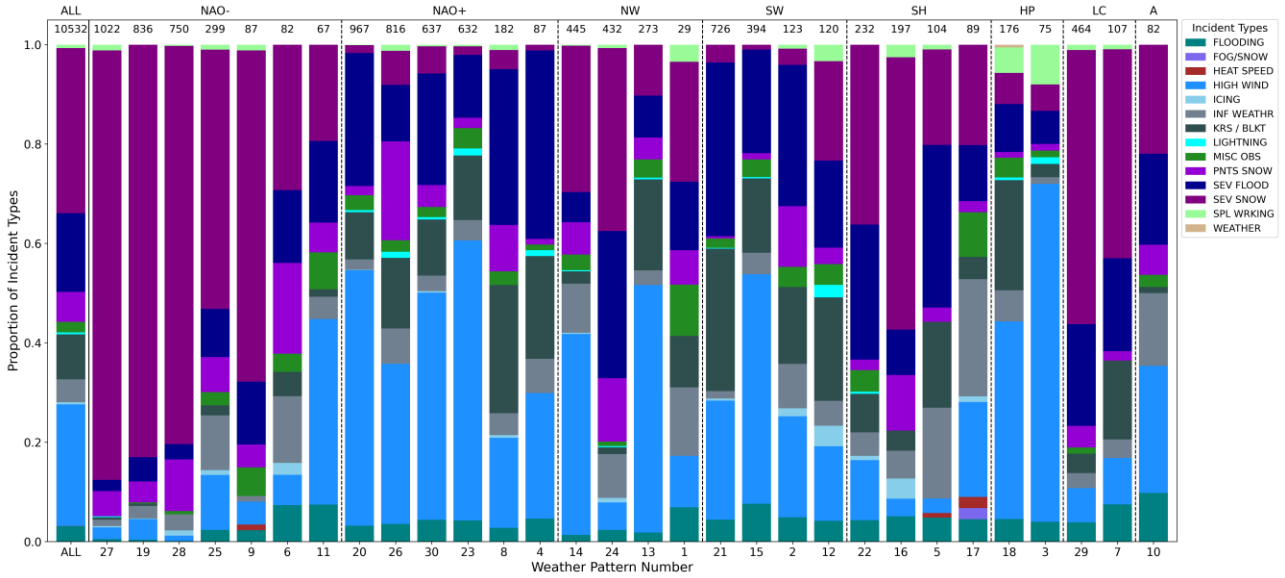
Compound cold events, impacts and weather patterns: a case study of the Scottish rail network. (in review)

Kanzis L. Mattu, Christopher J. White, Hannah Bloomfield and Joanne Robbins

- **Snow, wind, and precipitation hazards dominate winter rail disruption** across Scotland (2006–2023).
- **High-impact days are rare (top 1%) but account for a disproportionate share of disruption**—up to **31.5% of all PfPI (delay) minutes**.
- **Compound cold events (CD/CW)** are strongly associated with the **most disruptive days**, especially when they occur **in sequence**.
- **NAO−** patterns drive **snow-related incidents**; **NAO+** patterns drive **wind and flood-related incidents**.
- **Sequencing matters:** CW → CD transitions can lock in frozen precipitation and amplify impacts.



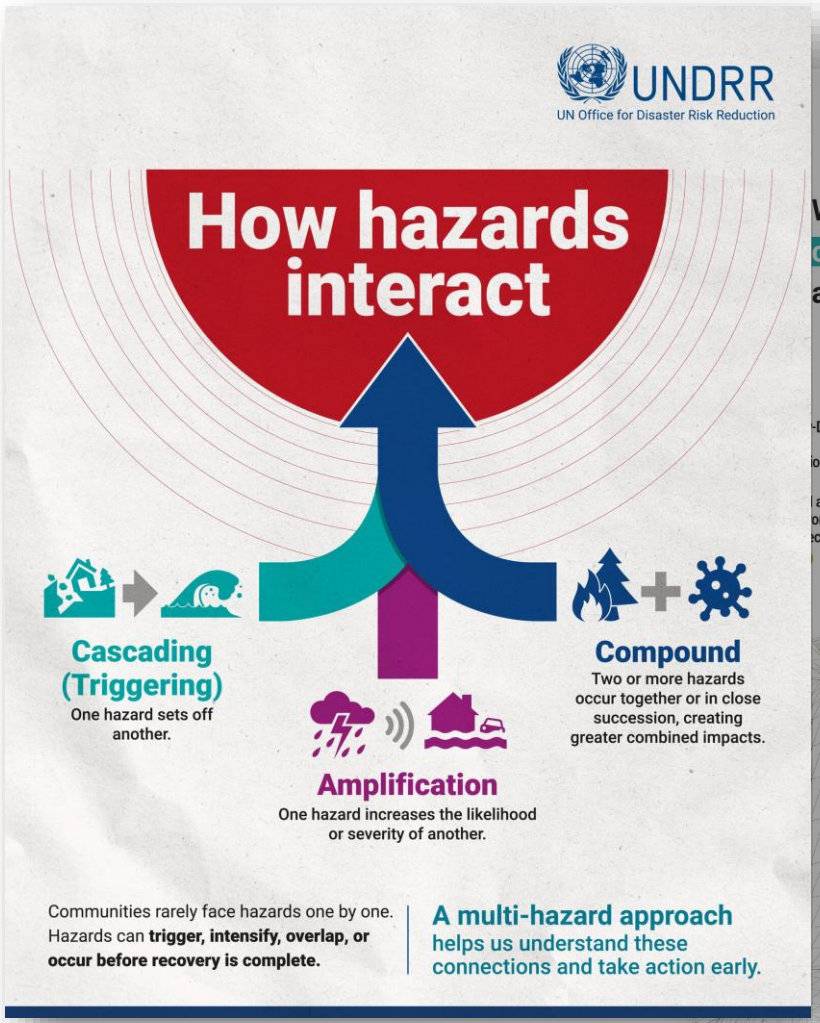
Frequency of reported rail incidents per incident reason, Oct-Mar, 2006-2023 in Scotland

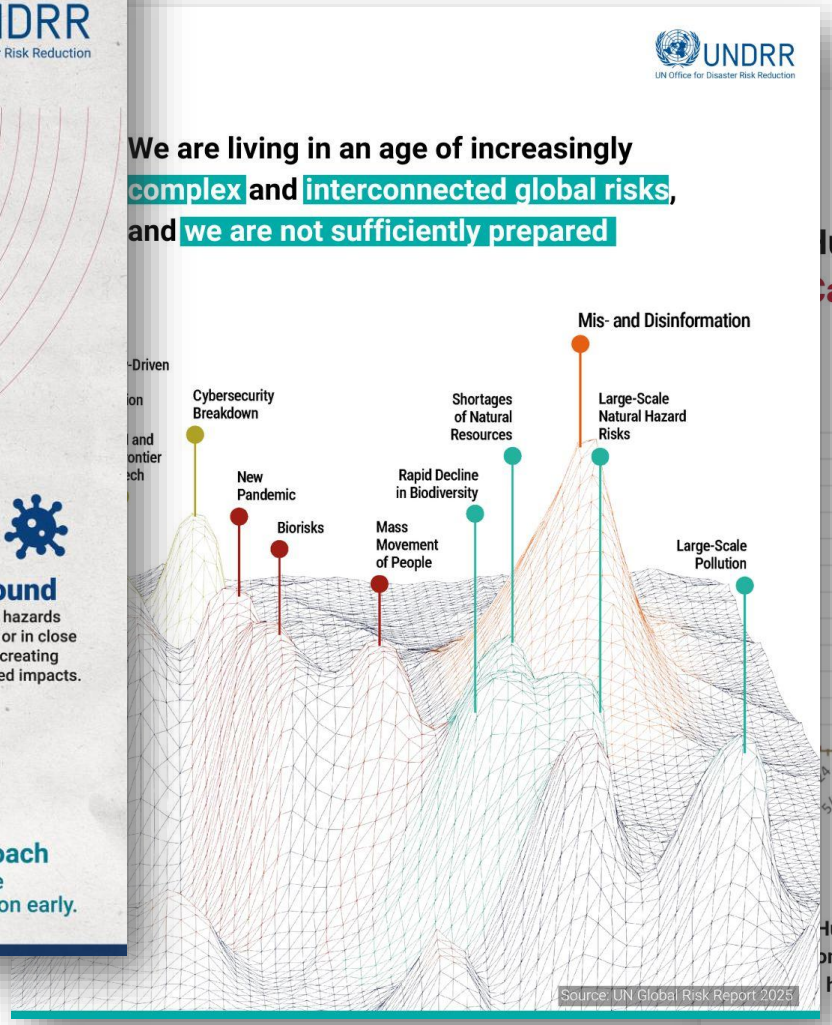


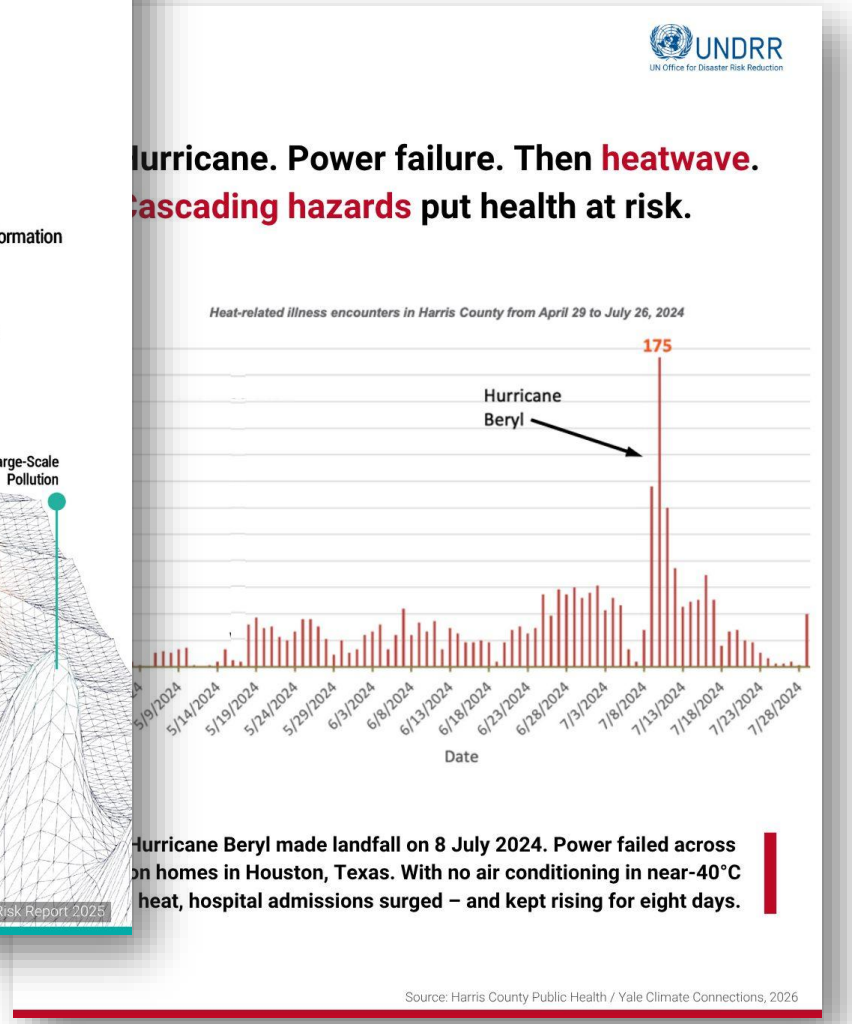
Proportion of rail incident type per MO30 weather pattern for the period Oct-Mar, 2006-2023 in Scotland

More than just hazards

UNDRR
UN Office for Disaster Risk Reduction







Sources: UNDRR & PreventionWeb https://www.preventionweb.net/understanding-disaster-risk/key-concepts/systemic-risk

Example: rain & canal failure closes mainline

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'Two months' to repair flood-damaged Glasgow-Edinburgh rail link

18 August 2020

NETWORK RAIL

Network Rail said thousands of gallons of water had poured onto the track from the Union Canal

A flood-damaged section of the rail link between Glasgow and Edinburgh could take two months to repair, Network Rail has said.

Sources: BBC and Network Rail

Communicating multi-hazards

Meteorological Applications
Science and Technology for Weather and Climate
Open Access
RMetS

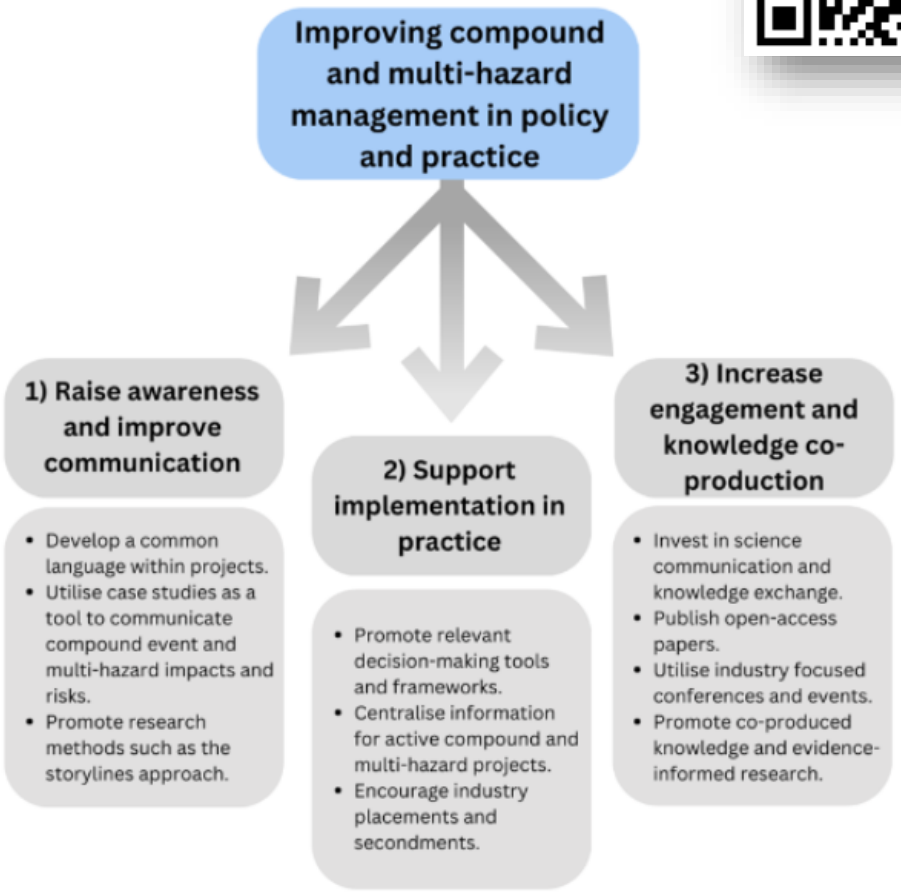
RESEARCH ARTICLE | Open Access

Science–policy–practice insights for compound and multi-hazard risks

Lou Brett, Hannah C. Bloomfield, Anna Bradley, Thibault Calvet, Adrian Champion, Silvia De Angeli, Marleen C. de Ruiter, Selma B. Guerreiro, John Hillier, David Jaroszweski, Bahareh Kamranzad, Minna M. Keinänen-Toivola, Kai Kornhuber, Katharina Küpfer, Colin Manning, Kanzis Mattu, Ellie Murtagh, Virginia Murray, Áine Ní Bhreasail, Fiachra O'Loughlin, Chris Parker, Maria Pregnolato, Alexandre M. Ramos, Julius Schlumberger, Dimitra Theochari, Philip Ward, Anke Wessels, Christopher J. White ... See fewer authors

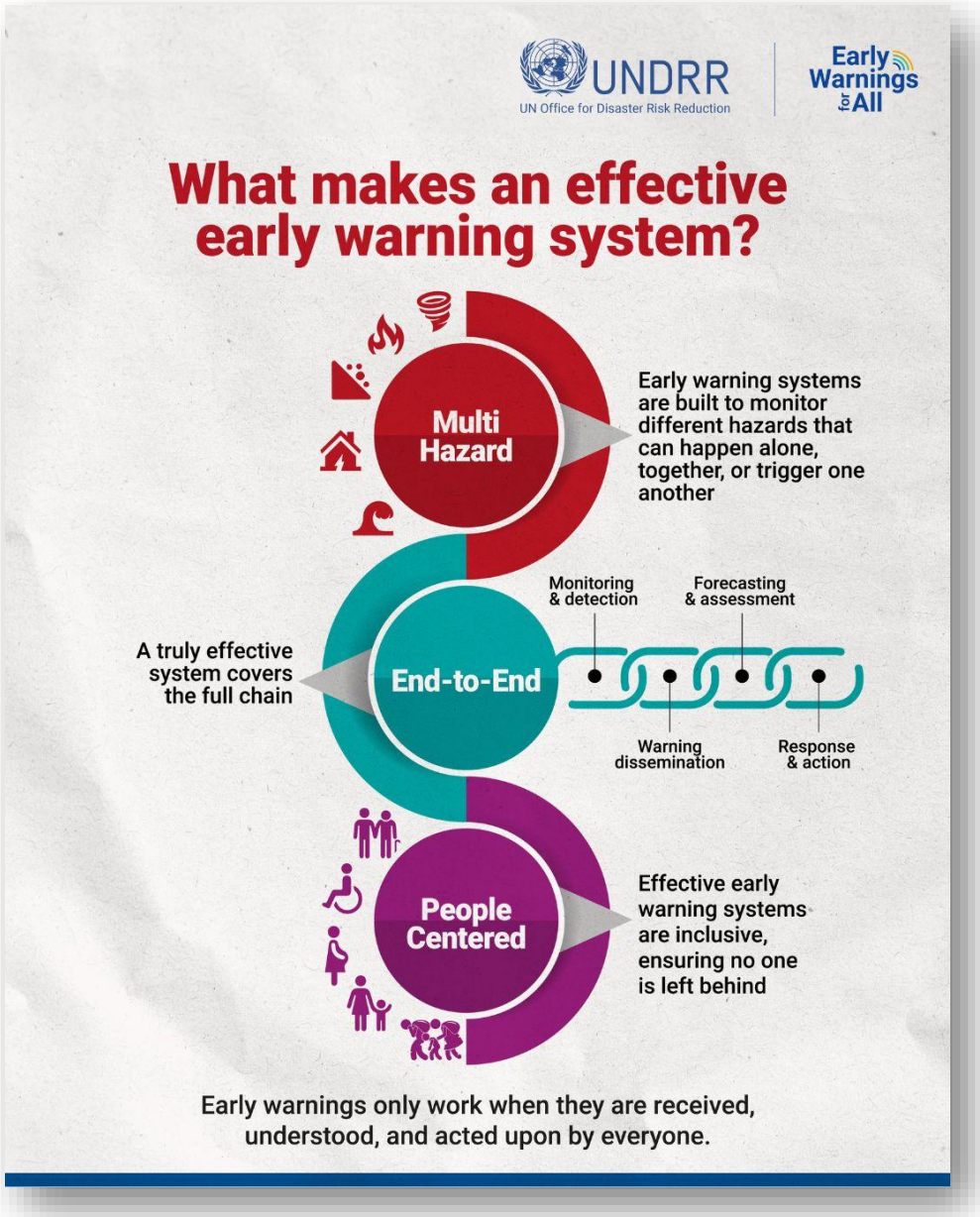
First published: 08 April 2025 | https://doi.org/10.1002/met.70043 | Citations: 2

- **Glasgow workshop (Jan 2023)**: Brought together 42 researchers, practitioners, and policymakers from 12 countries to build a shared understanding of compound and multi-hazard events and improve risk management across sectors.
- **Key themes**: Participants emphasized the need for a common language, effective case studies, knowledge co-production with practitioners, and better frameworks for managing compound and multi-hazard risks.
- **Practical outcomes**: Strategies included reclassifying past events, using storylines to project future impacts, adopting adaptive policy pathways, promoting open-access tools, and strengthening cross-disciplinary collaboration.

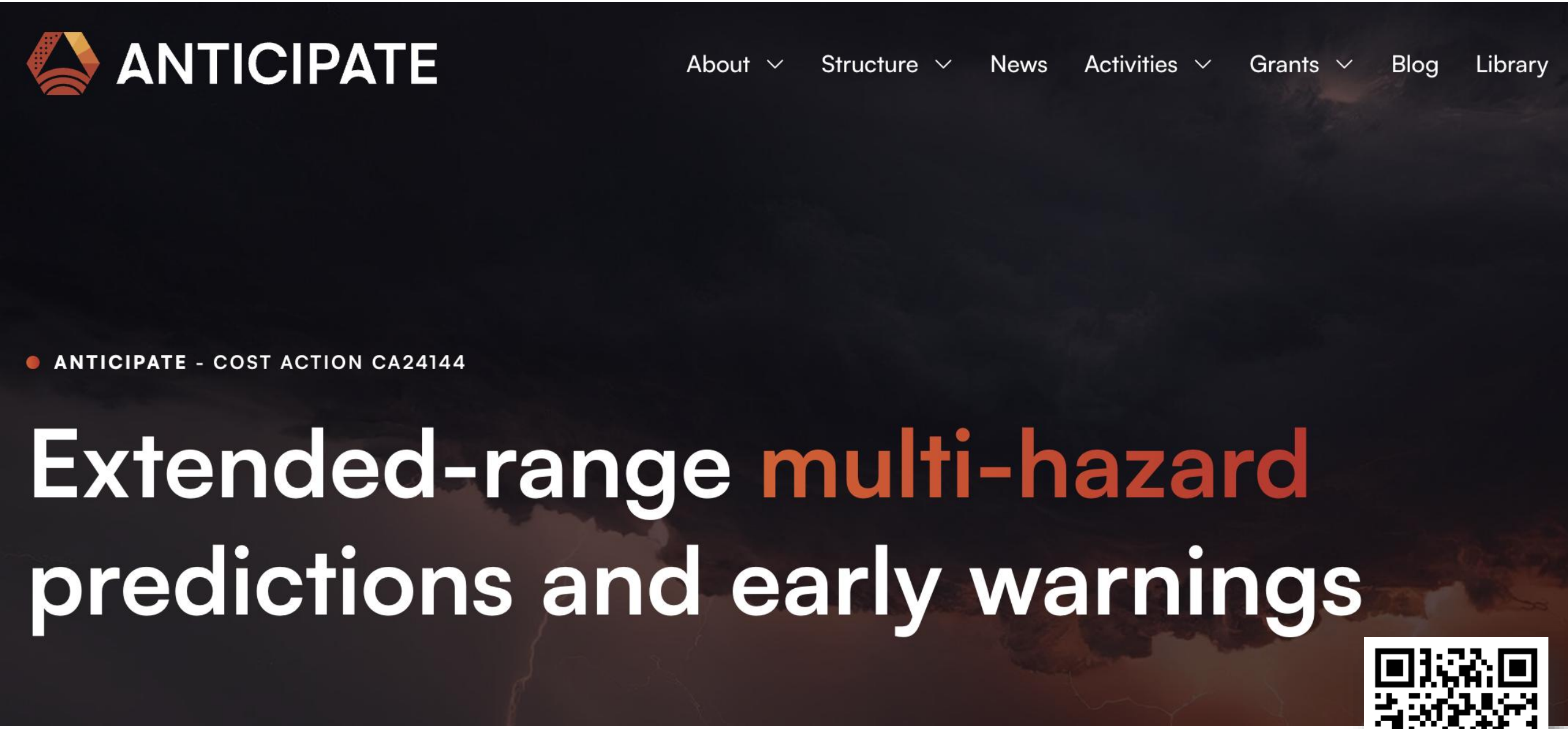


Schematic summarizing the identified high-level priorities for how to improve compound event and multi-hazard risk management in policy and practice.

Forecasting multi-hazards



Source: UNDRR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Extended-range multi-hazard predictions and early warnings
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Prof Christopher J. White

Director of the Centre for Water, Environment, Sustainability & Public Health

Department of Civil and Environmental Engineering, University of Strathclyde, Glasgow, UK

chris.white@strath.ac.uk

University of Strathclyde Glasgow

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Daily Mail University Guide

SCOTTISH UNIVERSITY OF THE YEAR 2026
The Times and Sunday Times Good University Guide

THE QUEEN'S ANNIVERSARY PRIZES 1996, 2019, 2021 & 2023
For Higher and Further Education

UK UNIVERSITY OF THE YEAR 2012 & 2019
Times Higher Education

Compound events in 2024:

Zscheischler, J., Raymond, C., White, C.J. *et al.* (2025). Compound weather and climate events in 2024. *Nat. Rev. Earth Environ.,* 6, 240–242
https://doi.org/10.1038/s43017-025-00657-y

ANTICIPATE COST Action:

The ANTICIPATE COST Action for extended-range multi-hazard predictions and early warnings
https://cost-anticipate.eu/