



CEC Flood Costing Project Enhancing the CEC Flood-Costing Method – Part II

2nd CEC Virtual Expert Workshop

Challenges in assessing the impacts of cascading hazards



22-23 October 2020



Example

- Drought → Fire ...time lag... Precipitation → Floods + Debris Flows...
 - Infrastructure damage → water system failures → public health impacts
 - Infrastructure damage → electricity transmission failures → technology failures, traffic lights/transportation risks...
 - Direct flood damage ...time lag... black mold → public health impacts



Methodology Framework:

Direct Damages, Indirect Effects & Losses

Social Sectors

- Housing
- Education
- Health
- Water and Sanitation
- Cultural Resources
- Local Government and Community

Infrastructure

- Transportation
- Energy and Utilities
- Technology and Communications
- Public Infrastructure

Economic Sectors

- Agriculture
- Fisheries
- Manufacturing
- Commerce
- Tourism
- Public Forests
- Environment

Emergency Assistance

- Emergency response



Definitions and Nomenclature

- United Nations Disaster Risk Reduction
 - Multi-hazard assessments
 - Systemic risk
- Multiple near-simultaneous hazards
- Compound drivers and hazards – more than one natural/earth-environment effect contribute to damages and losses
- Connected extreme events
- “Toppling dominoes” – one hazard triggers another
- Vulnerabilities in tightly coupled systems trigger hazards, where the initial natural hazard may cause less impact than amplifying events (e.g., Natural-technological “Natech” events)

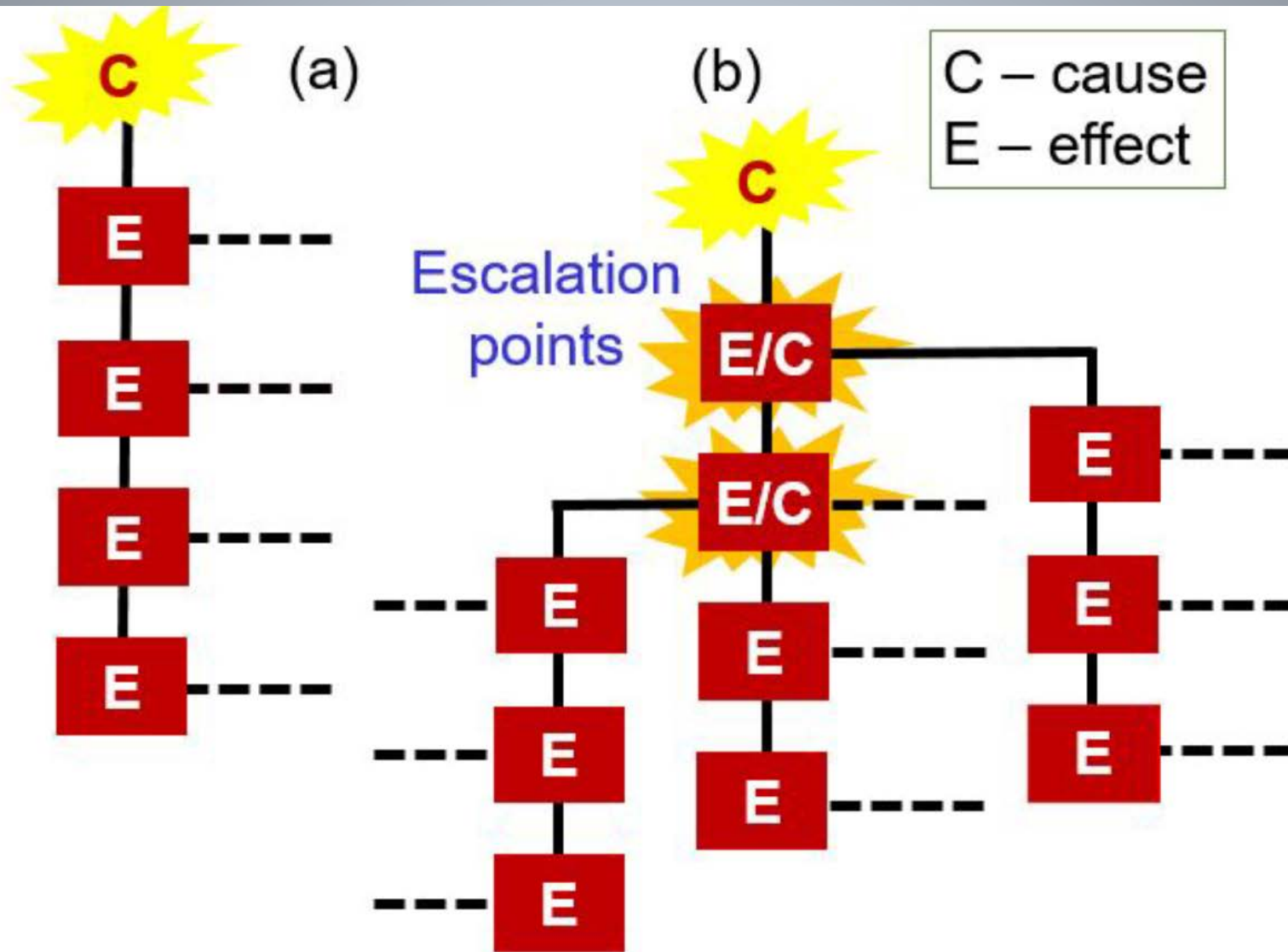


Figure 1: Cascading causes and effects.

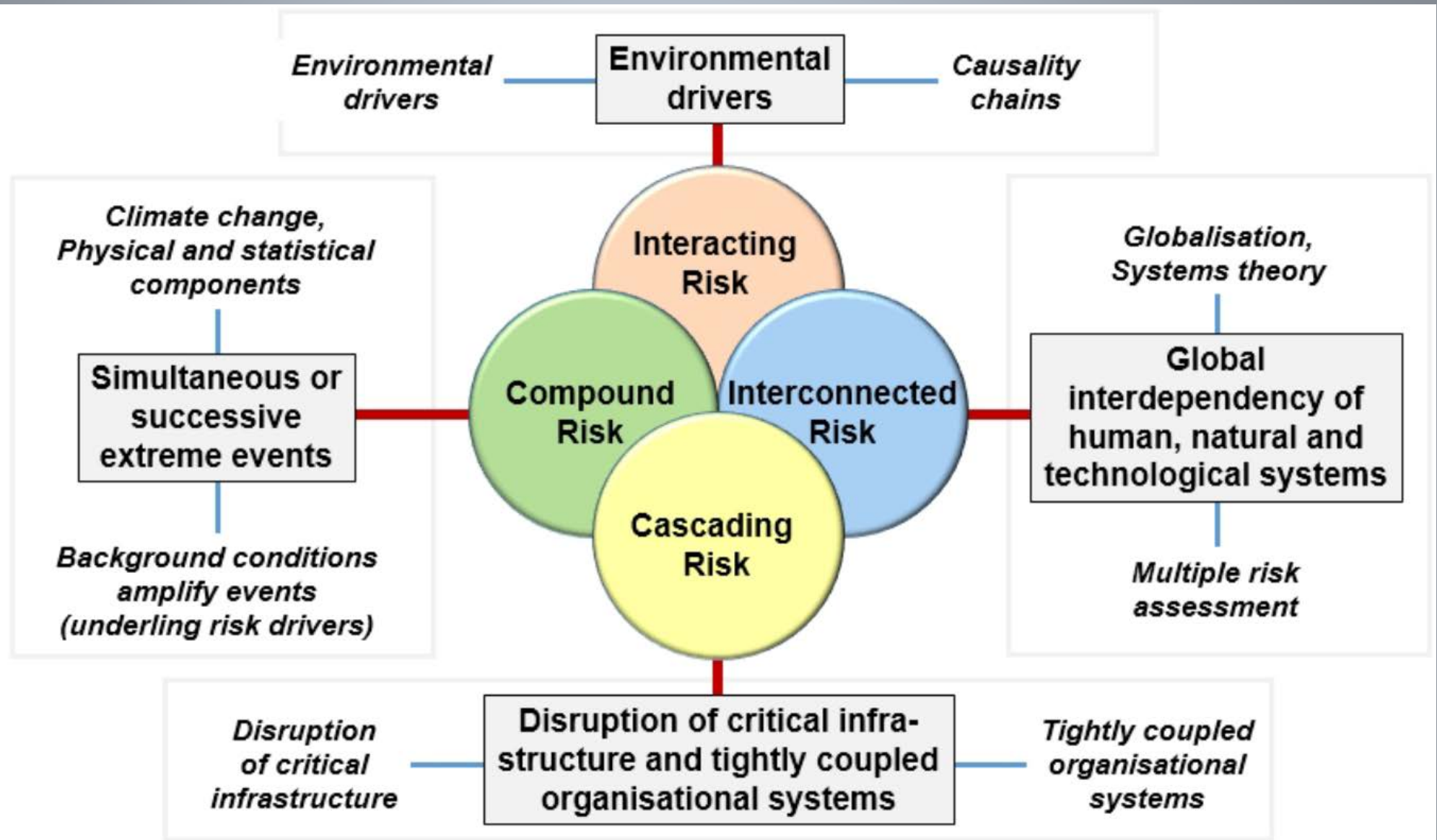


Figure 3: Compound, interconnected, interacting and cascading disasters.



Five kinds of complex disaster impact:

- Compound risk
- Interacting risks
- Interconnected risks
- Cascading impacts
- **Complex disasters**



Five kinds of complex disaster impact:

- **Compound risk** involves the interaction of **different extreme events** or their drivers, such as storms and sea-level rise.
- It can also involve events that are merely coincident in time, such as an earthquake during a period of intense cold weather.
- With a time lag, such as a fire that destroys soil structure when combined with a storm, months later, may trigger landslides or flooding + debris.



Five kinds of complex disaster impact:

- **Interacting risks** involve environmental drivers that can generate primary and secondary impacts, as with seismically-induced mass movements
- Superstorm Sandy – winds (direct damage) and storm surge (flood damage) – both from the same driver
- Tohoku – earthquake → triggers tsunami – same initial driver



Five kinds of complex disaster impact:

- **Interconnected risks** cover *the interaction of natural and human systems*.
- This category includes the so-called ‘na-tech’ events, in which a natural impact triggers a technological one.
- Hurricane Harvey – floods inundated industrial premises and caused fires, explosions and toxic smoke emissions
- Superstorm Sandy – floods affected interconnected financial and industrial networks



Five kinds of complex disaster impact:

- **Cascading impacts** disrupt critical infrastructure and closely linked organizational systems
- Superstorm Sandy – nonlinear escalation of impact through power outages, effects to supply chains
- Tohoku – the interconnected risks (earthquake → landslide → cut off Fukushima plant from electric grid), then cascaded to nuclear meltdown (*i.e., the crisis that needed to be managed*)

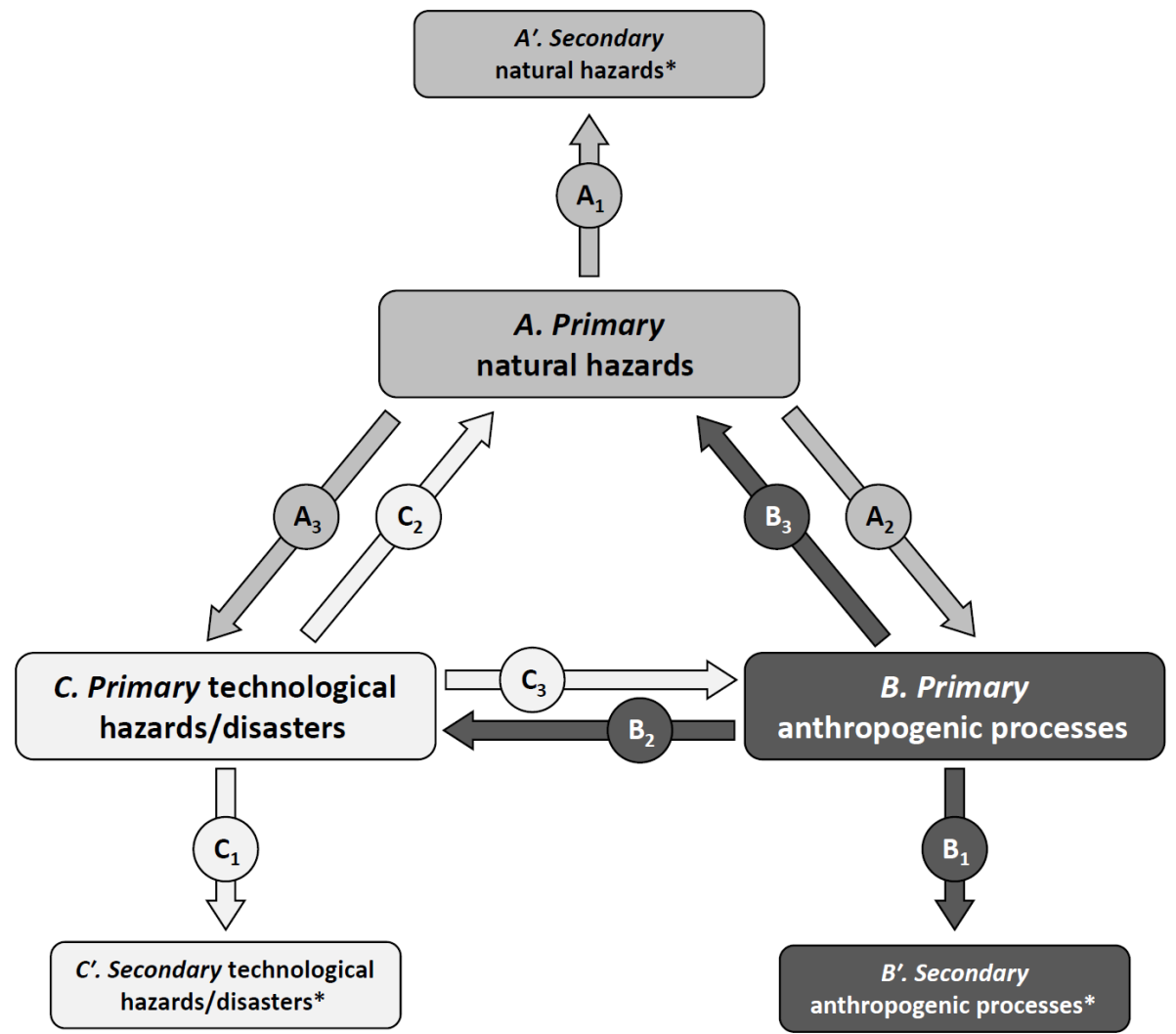


Five kinds of complex disaster impact:




- **Complex disasters *may involve elements of any or all* of the previous four categories.**



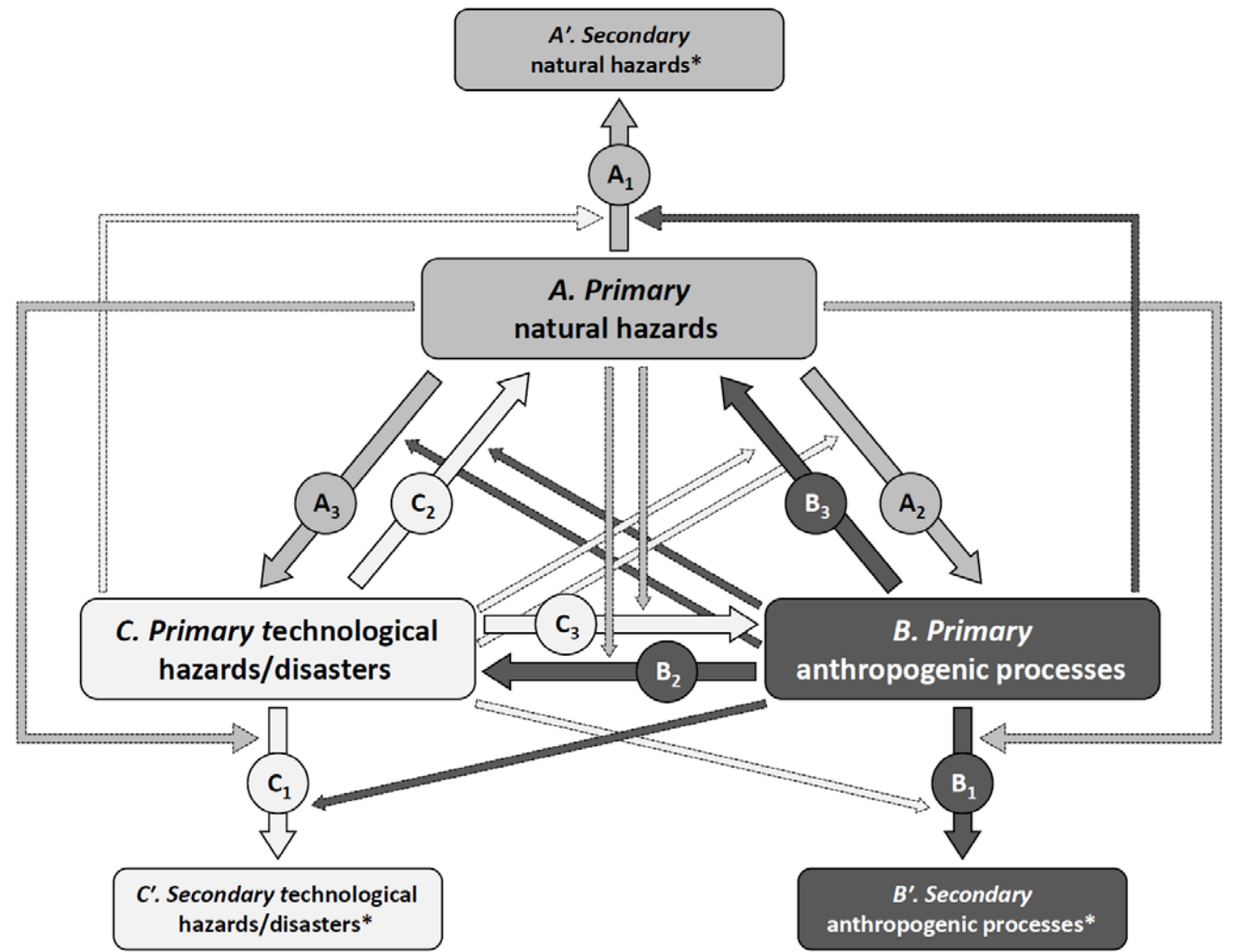
Hazard/process group	Examples
Natural hazards	Earthquake, tsunami, volcanic eruption, landslide, snow avalanche, flood, drought, regional subsidence, ground collapse, soil (local) subsidence, ground heave, storm, tornado, hailstorm, snowstorm, lightning, extreme temperature (hot and cold), wildfire, geomagnetic storm, impact event
Anthropogenic processes	Groundwater abstraction, subsurface mining, subsurface construction, fluid injection, vegetation removal, urbanisation, surface mining, drainage and dewatering, reservoir construction, wastewater injection, chemical explosion
Technological hazards/disasters	Structural collapse, nuclear reactor failure, urban fire, chemical pollution, dam collapse, industrial explosion, transport accident



Internal arrow fill

-  Interaction relationships initiated by natural hazards.
-  Interaction relationships initiated by anthropogenic processes.
-  Interaction relationships initiated by technological hazards/disasters.

**Secondary hazards may initiate further interactions.*



Key:

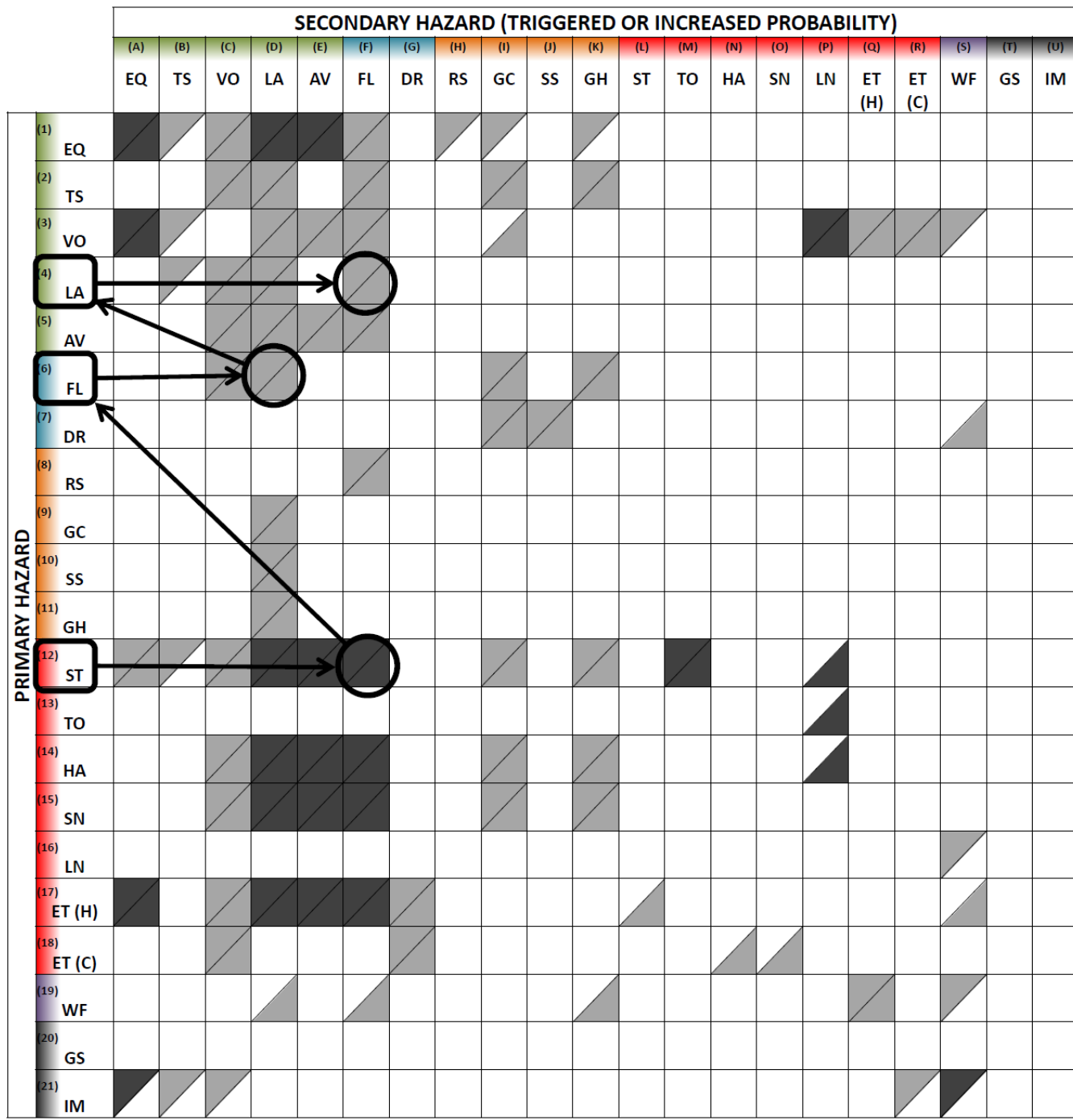
Internal arrow fill

- Relationships initiated by natural hazards (e.g., A₁-A₃).**
- Relationships initiated by anthropogenic processes (e.g., B₁-B₃).**
- Relationships initiated by technological hazards/disasters (e.g., C₁-C₃).**

External arrow line

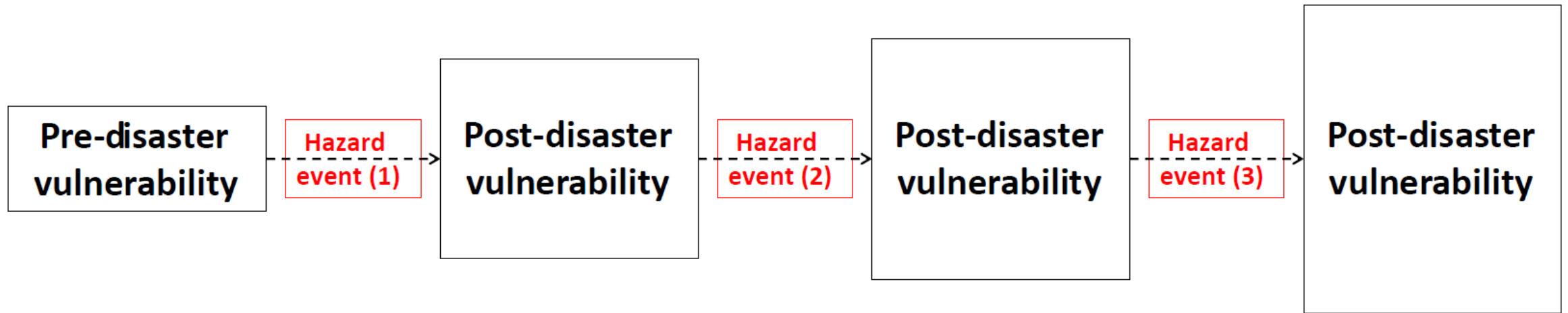
- Triggering/driving relationship**
- Catalysing and impeding relationships**

*Secondary hazards may initiate further interactions.



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	Wildfire	WF
SPACE	Geomagnetic Storm	GS
	Impact Event	IM

COLOUR CODE	NATURE OF SECONDARY HAZARD (FOLLOWING <u>ONE</u> 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





Compound weather and climate events are comprised of multiple distinguishable physical drivers and/or hazards and their risks. These can be subdivided according to the primary means of interaction:

- **temporal compounding** (for example, a sequence of storms)
- **spatial compounding** (for example, synchronous crop failures)
- **preconditioning** (for example, rain-on-snow flooding)
- **concurrence of multiple variables** (for example, storm surge, pluvial flooding and high winds from a single storm)



Compound event impacts are often substantially and **nonlinearly influenced by non-physical factors such as exposure and vulnerability**, cutting across sectors and scales (from personal to society wide).

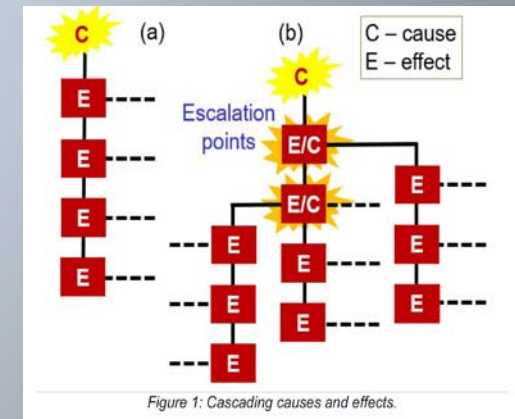
These ‘**societal mechanisms**’ can tie together the impacts from two or more climate extremes:

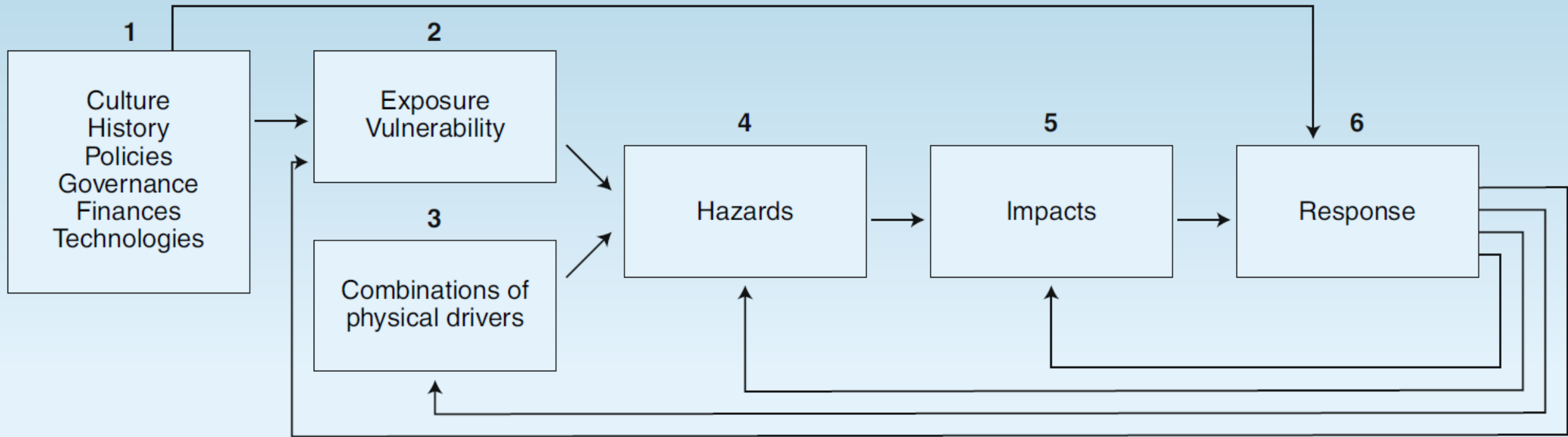
- whether due to **resource constraints** (for example, exhaustion of an insurance fund or pool of emergency responders)
- **health considerations** (for example, power outages or medication-supply-chain disruptions)
- or **other linkages**

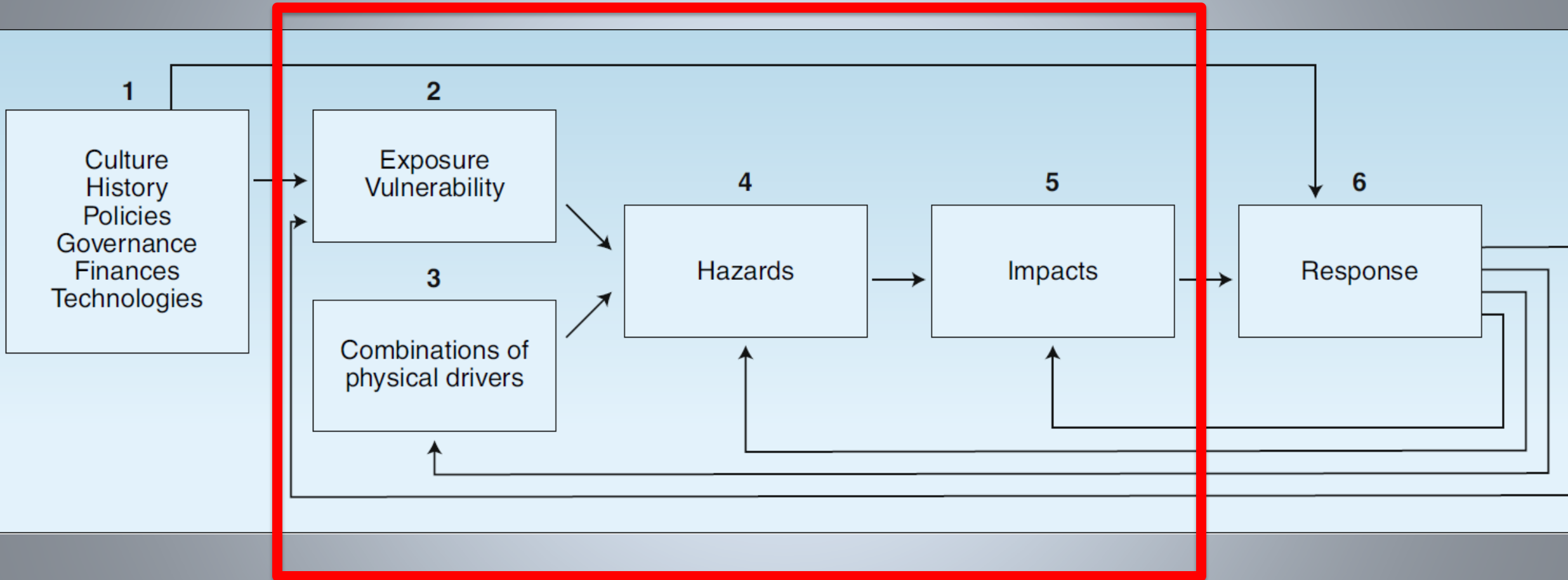


Connected events –

- to convey the diversity and complexity of interacting physical and societal mechanisms that cause their impacts to be **amplified relative to the impacts from those same events occurring separately or univariately**









Example

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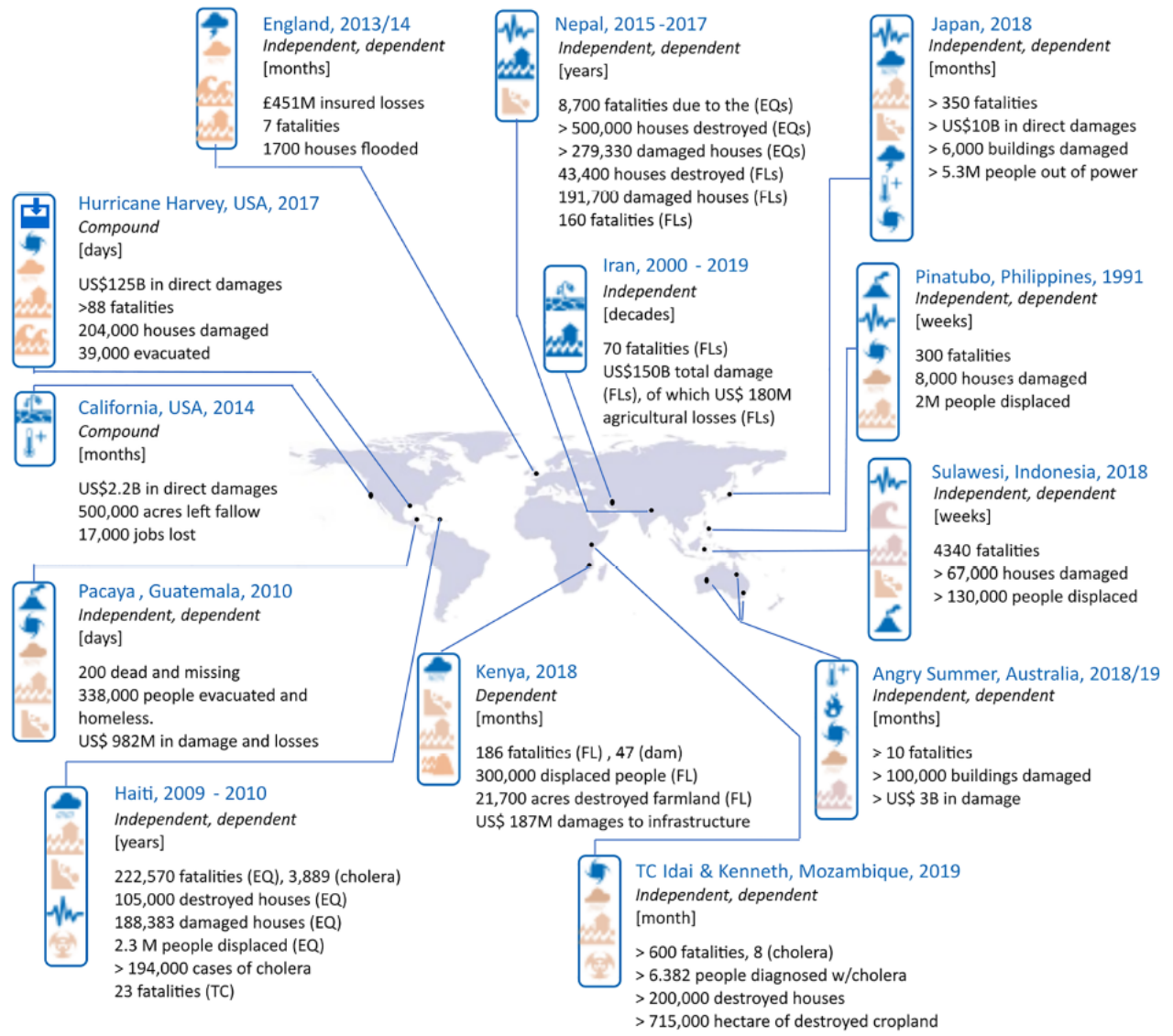
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- | | | | |
|------------------|------------------------|-------------------------|--------------------|
| Cyclone | Flood (FL) | Storm Surge | Independent hazard |
| Dam Breach | Heatwave (HW) | Technological disaster | Dependent hazard |
| Drought (DR) | Heavy rain | Tsunami | |
| Earthquake (EQ) | Volcanic eruption (VE) | | |
| Epidemic | Land/Mudslide | <i>External drivers</i> | |
| (Wild)fires (WF) | Storm | Subsidence | |

Source pictograms: UNOCHA

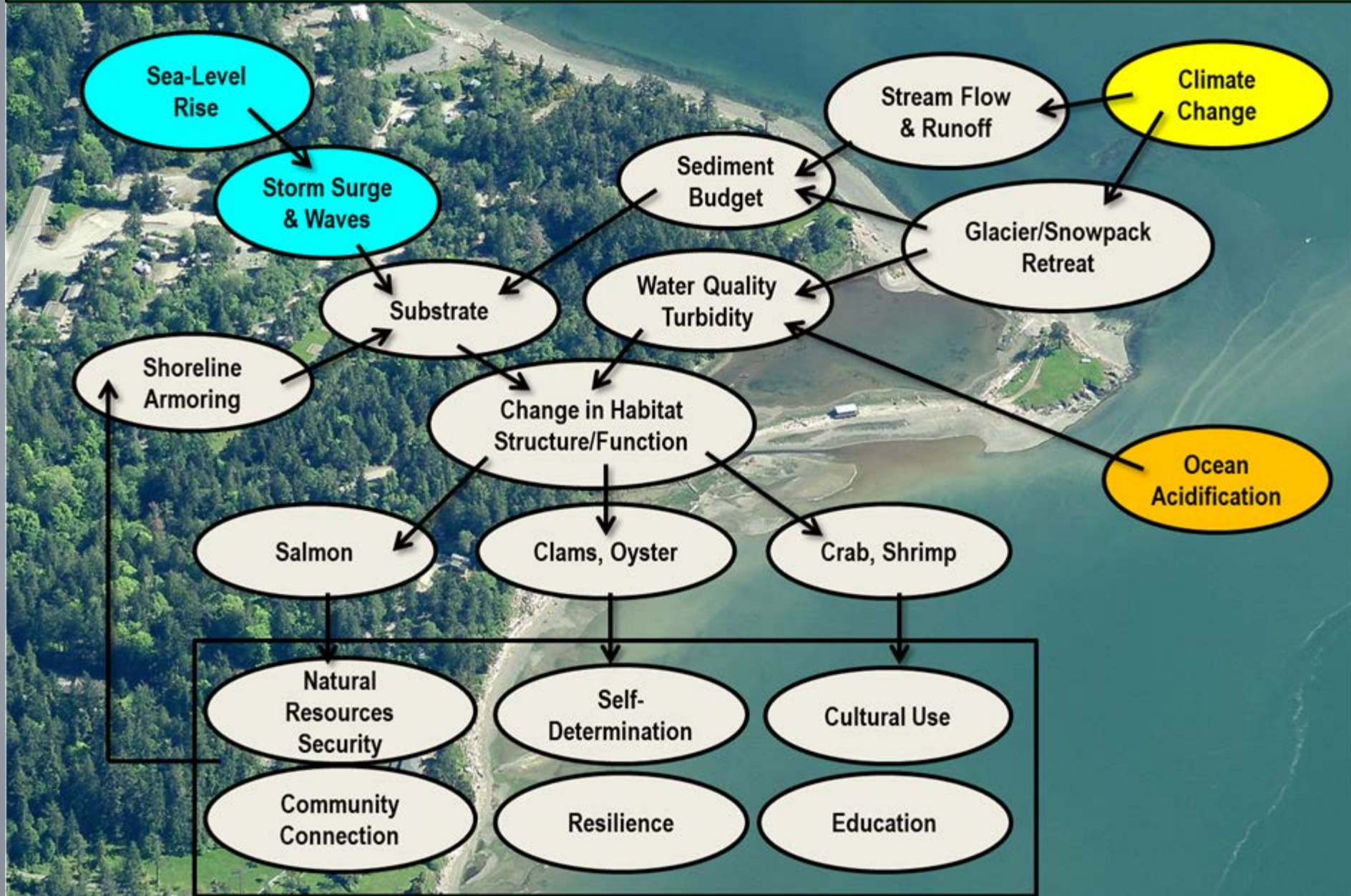


Compound weather and climate events – examples

- **Drought + heat → wildfires → air pollution → impact public health + crops (Russia summer 2010)**
- **Hurricanes → heavy rain + winds + surge → impact infrastructure and human life**



Coastal Climate Change Impacts to Swinomish First Foods and Indigenous Health Indicators

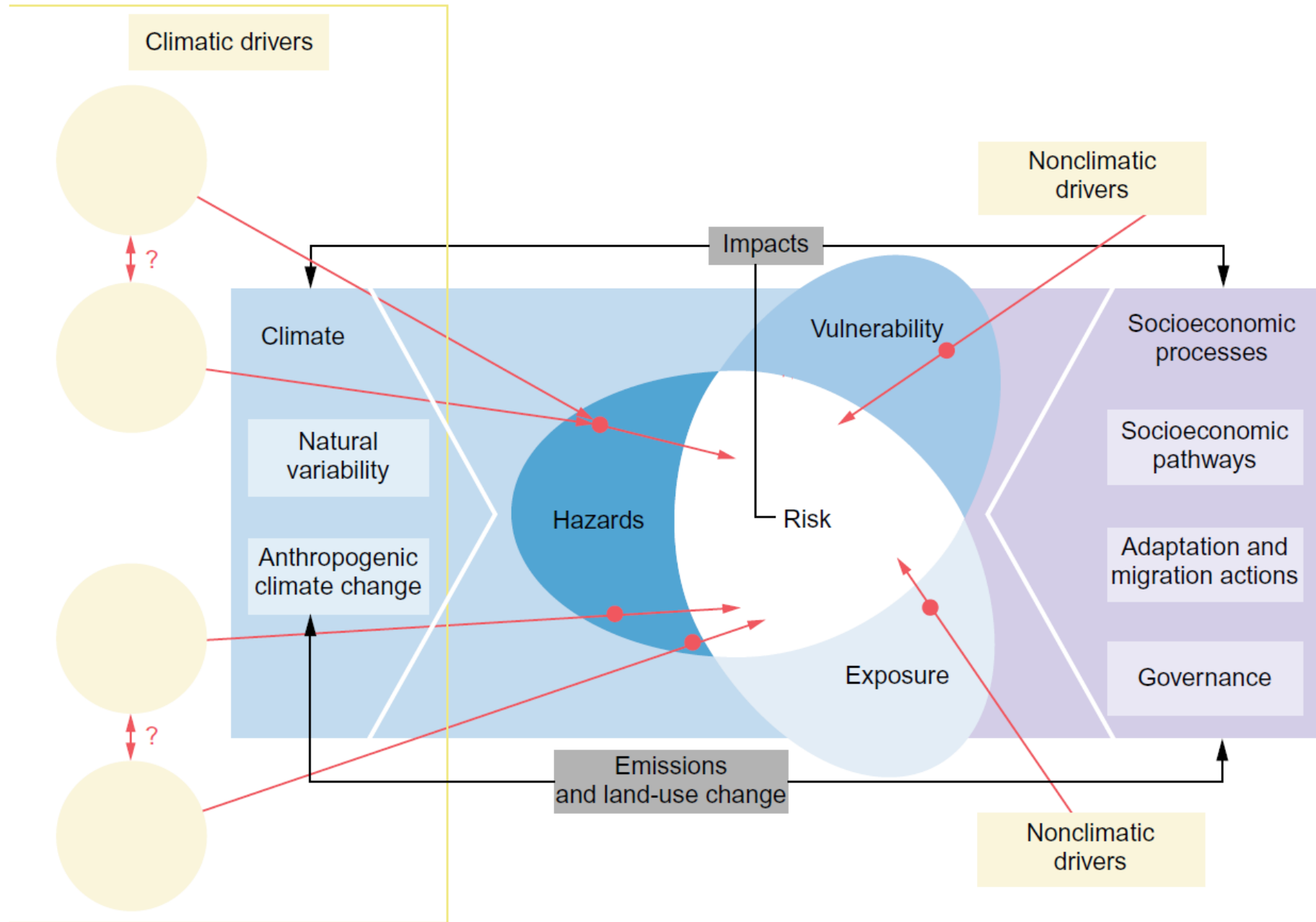




Is the impact of an extreme hydrometeorological event conditional on multiple drivers? In other words, would the impact be stronger/ less strong if other conditions would have prevailed?

Are other conditions causally related to the main drivers of the high-impact event, for instance, by sharing a causal relationship with a meteorological flow condition, or by spatial dependencies induced by topography (downstream/ upstream dependencies)?

Finally, can nonclimatic elements be identified that have aggravated or reduced the impact?





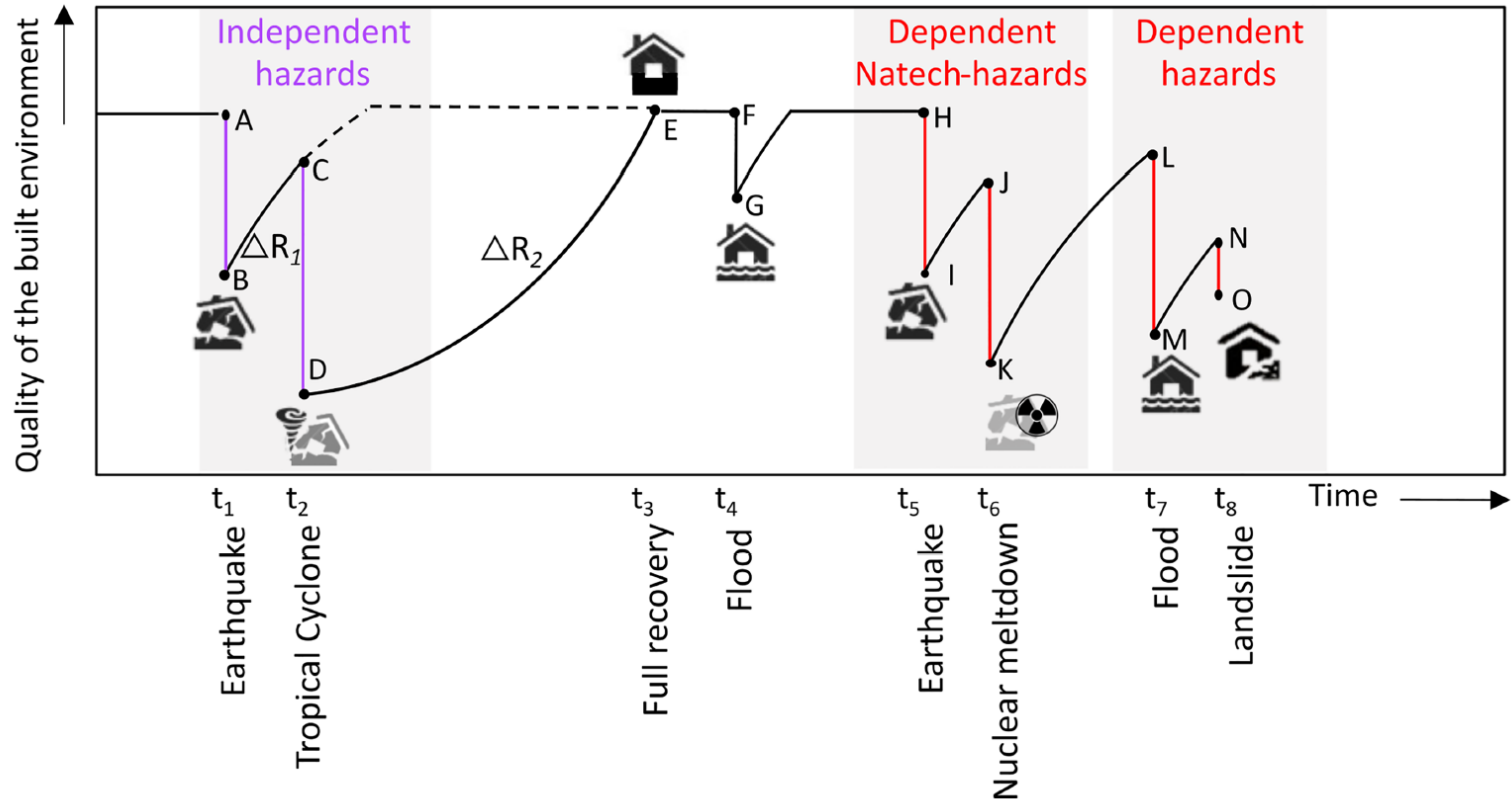
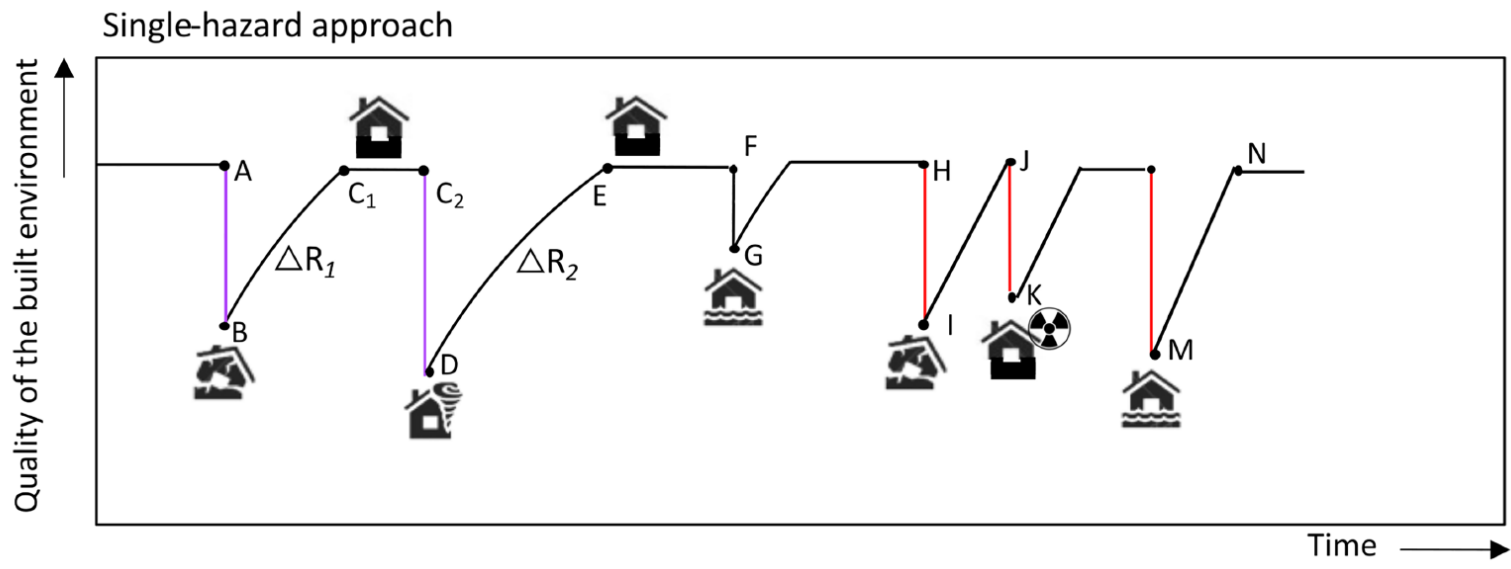
Consecutive Disasters:

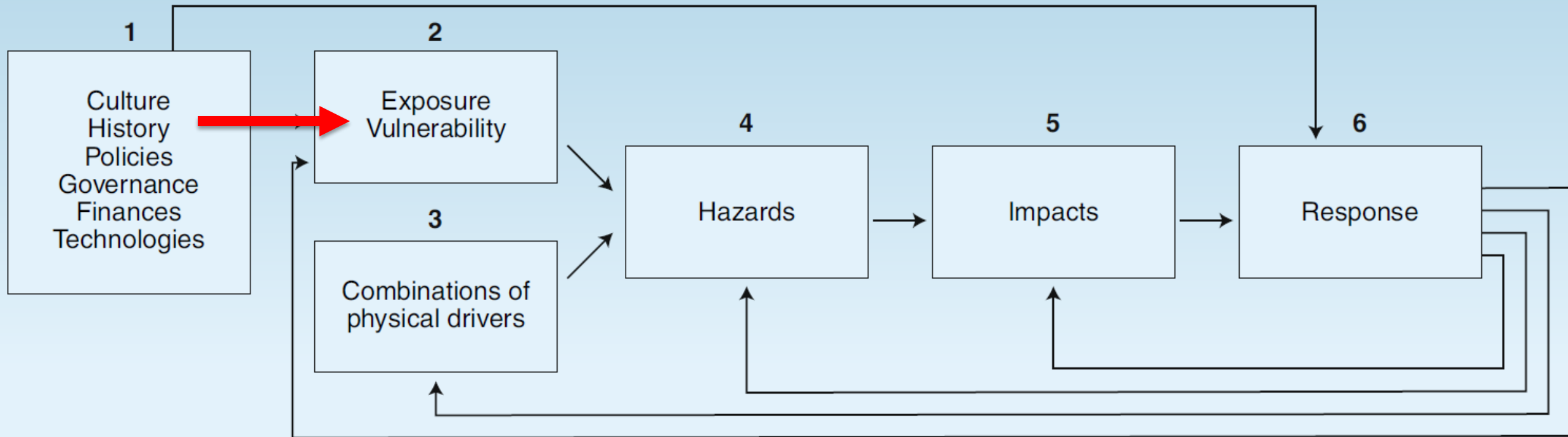
- two or more disasters that occur in succession, and whose direct *impacts* overlap spatially before recovery from a previous event is considered to be completed. This can include a broad range of multihazard types, such as compound events and cascading events.

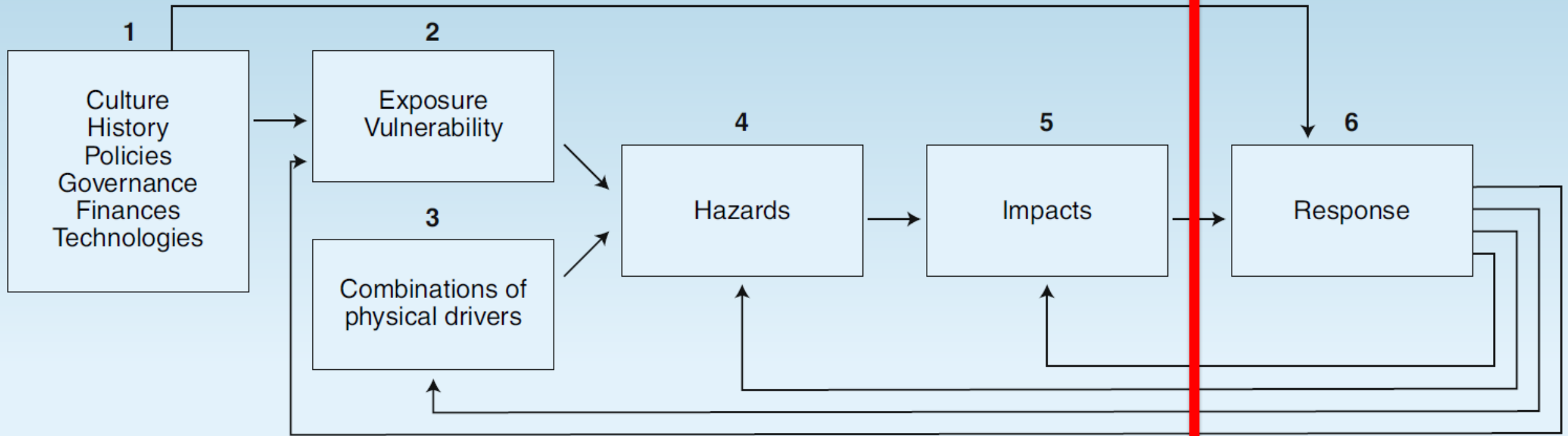


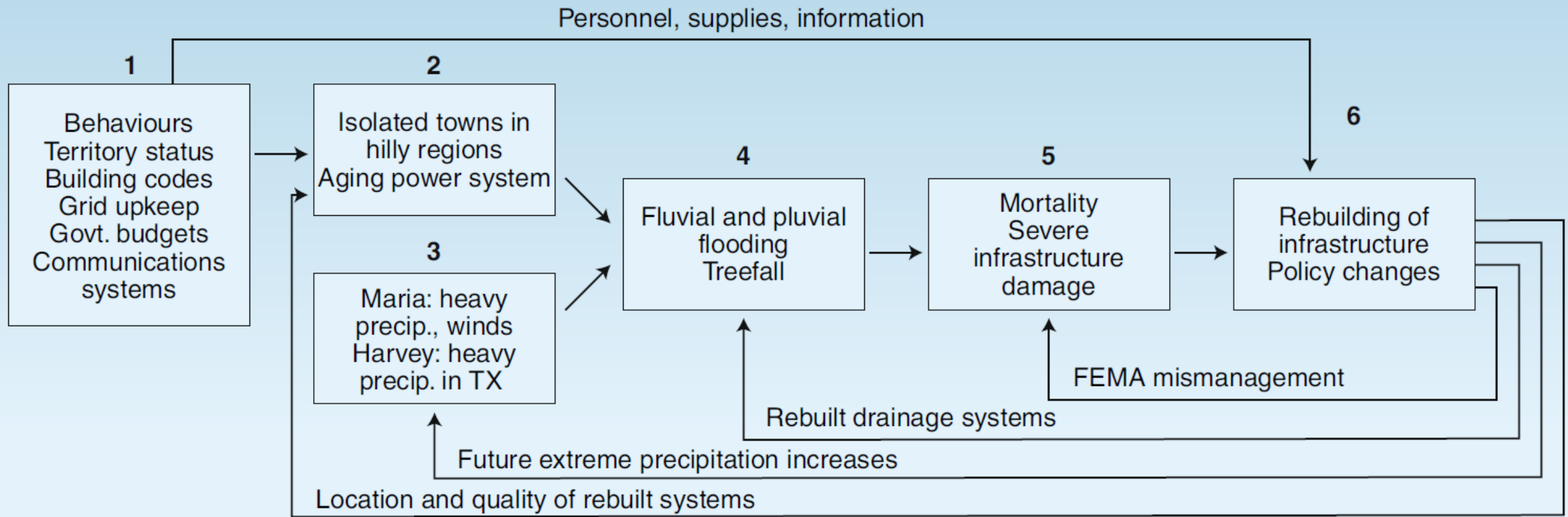
Consecutive Disasters:

- Direct impacts are interpreted in a broad sense encompassing both tangible and intangible direct impacts, with examples including damage to physical infrastructure, loss of lives, decreasing the capacity of key institutions (e.g., hospitals), and welfare.
- Consecutive disasters can occur due to dependency between natural hazards (e.g., triggering events) or when independent hazards occur in the same space-time window.











It is the creation or **strengthening of the connections between events, in the impacts space and involving anthropogenic systems**, that leads to our terminology of ‘connected’ events as being distinct from ‘compound’ events, and also from interacting-risk or multi-risk frameworks that focus on combinations of physical hazards