IRDR: State of Science

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Chair, IRDR Scientific Committee

A RESOLUTION of the
INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS
Adopted by the IUGG Bureau 10 January 2005

Whereas, A magnitude 9 great earthquake that occurred on 26 December 2004 off the west coast of northern Sumatra, South Asia, triggered tsunamis that inundated the coastal zones around the Indian Ocean resulting in tragic and historic loss of life and property;

The International Union of Geodesy and Geophysics (IUGG)

Recognizing, That tsunami warning systems in the Pacific Ocean have proved to be effective over several decades; and

Noting, That existing technology such as Synthetic Aperture Radar Interferometry (InSAR) observations for topography, real-time monitoring of marine activity, satellite observations from space, and natural hazard prediction models (e.g., tsunami propagation models) could prevent loss of life if predictions were timely and warnings were heeded; and

2. That the economic impact of natural disasters exceeds the cost of mitigation; and
3. That in the aftermath of a natural disaster, existing technology could provide rescue agencies and civil defense managers immediate quantitative estimates of the extent and severity of the disaster; and
4. That the reduction of predictive uncertainty is the most important scientific agenda in natural hazards reduction;

Recommends, That systems and procedures be prescribed for early warning, public awareness, regional evacuation routes and shelters based on charts of natural hazards, vulnerability, and risk assessments; and

2. That regional disaster management centers be established where they do not now exist to catalog information on the population and infrastructure at risk, and to monitor land, ocean and atmosphere in relation to all kinds of natural hazards; and
3. That regional tsunami warning systems be set up in order to generate and disseminate timely and accurate information needed by decision makers and the public; and
4. That multidisciplinary and multinational research programs and research networks on geophysical hazards and risks be developed to integrate diverse data streams, to improve understanding of the natural phenomena associated with the disasters, and to develop predictive modeling capability; and

Resolves, To promote the development and application of scientific expertise and experience in modeling and visualization of physical, technological, biological and social processes and their implications to the mitigation of natural disasters; and

2. To share this critical information to the greatest extent possible with government officials, emergency planners, the insurance industry, policy makers, and the public.

At the ICSU General Assembly in Maputo, Mozambique, 2008

IRDR
Integrated Research on Disaster Risk

International Science Council

UNDRR
UN Office for Disaster Risk Reduction

Coordination, oversight and institutional support by Co-Sponsors, Donor and Host

IRDR Mission

is to mobilize science for the reduction of all types of disaster risk, contributing to building resilience and reducing vulnerability by integrating risk science with climate change adaptation and mitigation and sustainable development.

This mission requires IRDR to bring together expertise from sciences, technologies, engineering and other fields. Engaging and working with relevant stakeholders, IRDR wishes to :

● improve knowledge and understanding of risk and uncertainty that hamper progress toward inclusive, safe and sustainable development;

● promote innovation in research and action, and explore effective solutions in DRR;

● build institutional capacity required under various socio-economic and cultural settings and development contexts for risk-informed sustainable development.

Mandate of the IRDR Scientific Committee

The Scientific Committee (hereafter referred to as SC) is established to guide IRDR as an international scientific programme and ensure that IRDR is strategic, open, inclusive, productive and impactful through the entire period of implementation.

- The first and foremost mandate of the SC is ***to provide scientific and policy guidance to the IRDR community and the IRDR IPO in programme planning, implementation, development and evaluation.*** This scientific and policy guidance is based on the collective expertise and deliberations of SC members and shall take the form of SC decisions and recommendations.
- The SC is further mandated ***to provide advice from a science-policy nexus to the cosponsors on the overall alignment of IRDR's work with the global implementation of the Sendai Framework for Disaster Risk Reduction and other related UN Agreements such as Agenda 2030***, paying particular attention to new and emerging risks, compound and cascading risks, and the international scientific response required thereto.

Specific task is to advance interdisciplinary science in DRR building on the Research Framework and on needs from the IRDR Co-Sponsors. This will involve thought leadership and scoping new areas for scientific collaboration, broad-based consultations on current and emerging issues, the continued monitoring of developments in the DRR field._

Priority 1: Understand risk creation and perpetuation in the present risk landscape
Priority 2: Address inequalities, injustices and marginalisation
Priority 3: Enable transformative governance and action
Priority 4: Understand the implications of new thinking on hazards
Priority 5: Harness technologies, data and knowledge for risk reduction
Priority 6: Support regional and national science and knowledge for policy and action
Priority 7: Support just and equitable transitions, adaptation and risk reduction
Priority 8: Measurement to help drive progress
Priority 9: Foster interdisciplinary and multi-stakeholder collaboration

IRDR will undertake four clusters of actions and lead the development and implementation of a global risk research agenda for 2030, as has been entrusted in the ISC Action Plan 2025-2027:

- **Enabling a full operation of IRDR Phase II,**
- **Coordination and facilitation of international research cooperation,**
- **Knowledge production, synthesis, and outreach, and**
- **Empower young DRR professionals.**

Outline of this talk

Key Emerging Topics in Disaster Science

&

DRR Frontier Research Questions

Key Emerging Topics in Disaster Science

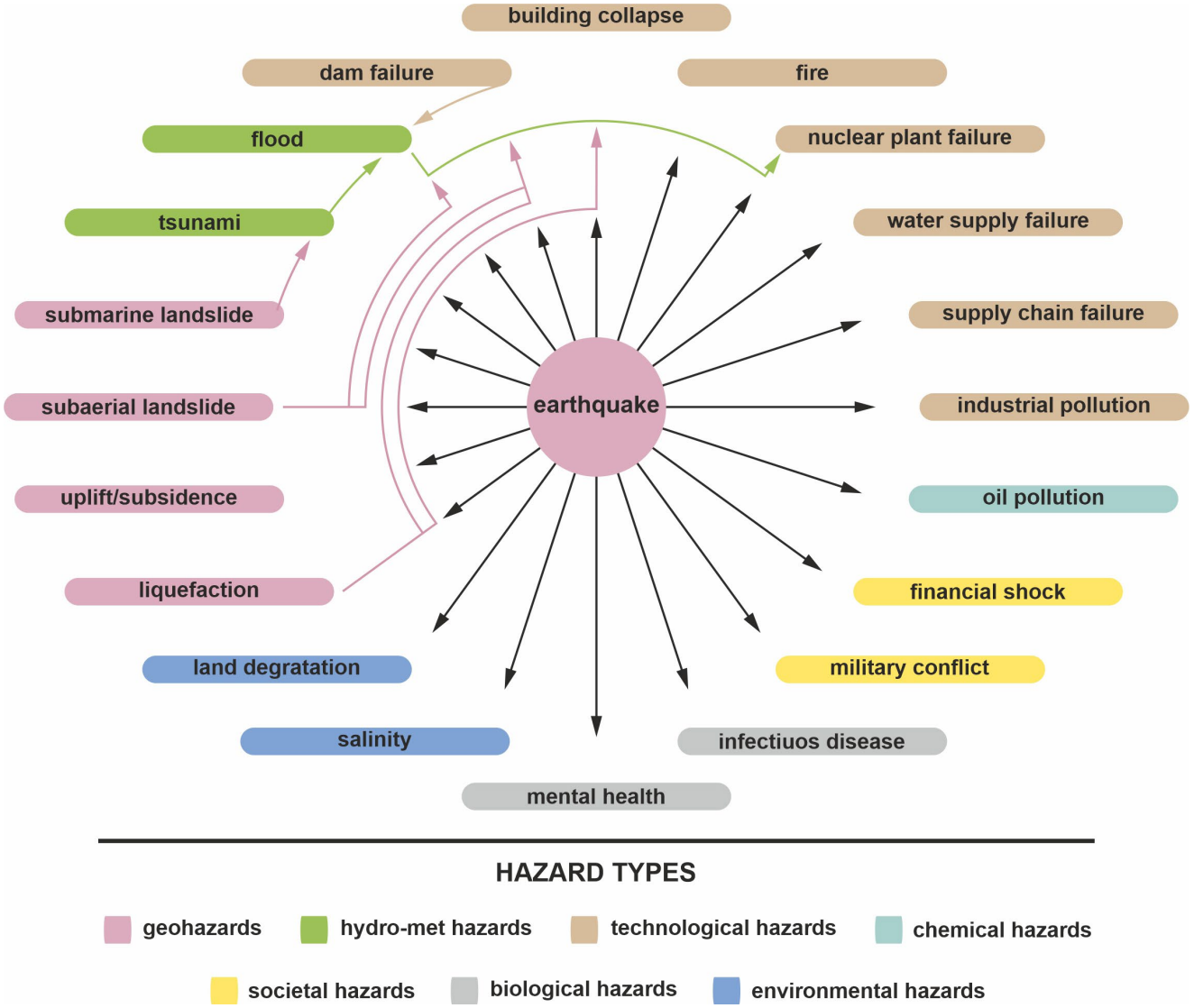
1. Multi-Hazard & Disaster Risks

Disasters often do not occur in isolation: e.g. an earthquake may trigger all types of hazard events and lead to multi-hazard disasters.

Understanding cascading hazards risks, compounding hazards, system interdependencies is increasingly vital.

Key Emerging Topics in Disaster Science

A large earthquake may trigger other hazard events, including **landslides** (as happened after the 2008 Wenchuan earthquake), **tsunamis** (triggered by the 2004 Sumatra–Andaman or 2011 Tohoku earthquakes) -- these are well-known events -- but also, **dam failure** (as happened after the 1965 Chile M7.4 earthquake, which generated sand liquefaction, failures of sand dams, flooding led to fatalities and widespread contamination of an agricultural valley), **fires**, **disease outbreaks** (for example, cholera after the 2010 Haiti earthquake), **environmental hazards** (for example, environmental and health hazards due to the 2023 Türkiye–Syria earthquake), and **technological hazards** (e.g., the 2011 Tohoku earthquake and tsunami followed by seawater inundation and flooding, which led to a loss of power in the cooling systems, core meltdowns at the Fukushima Daiichi nuclear power plant, and the nuclear incident), just mentioned a few.



Ismail-Zadeh, NJP | Nat. Hazard, 2024

Key Emerging Topics in Disaster Science

AI-generated image

System Interdependencies & Risk Amplification

- Infrastructure and social systems are interconnected, creating dependencies that influence overall stability.
- Failures in one system can spread to others amplifying risks and disaster impacts.
- System interdependencies can significantly escalate the severity and consequences of disasters.

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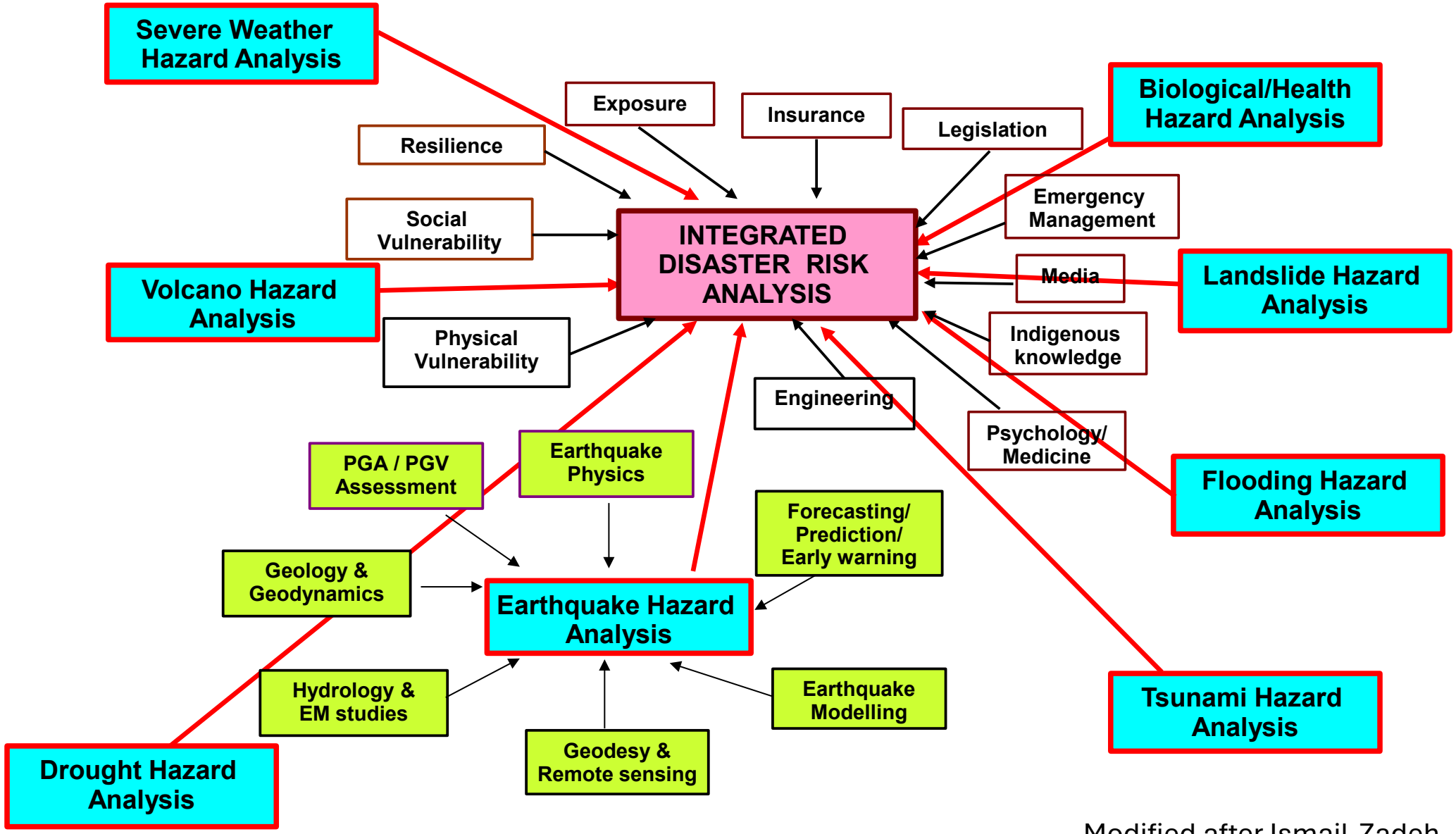
"The Mind's I" by D.R. Hofstadter & D.C.Dennett (Part 1 by Harold J. Morowitz)

Holistic assessments guide better emergency response and risk mitigation planning.

Analyzing how *hazards interact can reveal compound risks*, which is crucial for effective preparedness.

Key Emerging Topics in Disaster Science



Integrated frameworks can evaluate multiple hazards collectively for a *comprehensive disaster risk understanding*.

Modified after Ismail-Zadeh, NJP | Nat. Hazard, 2024

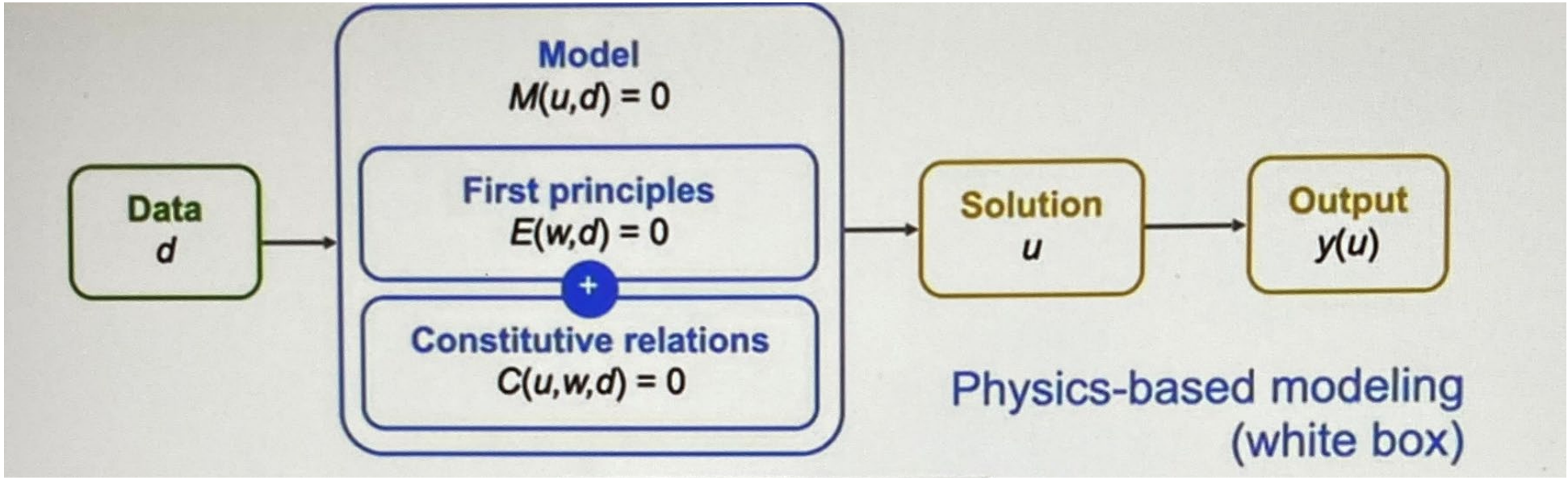
Key Emerging Topics in Disaster Science

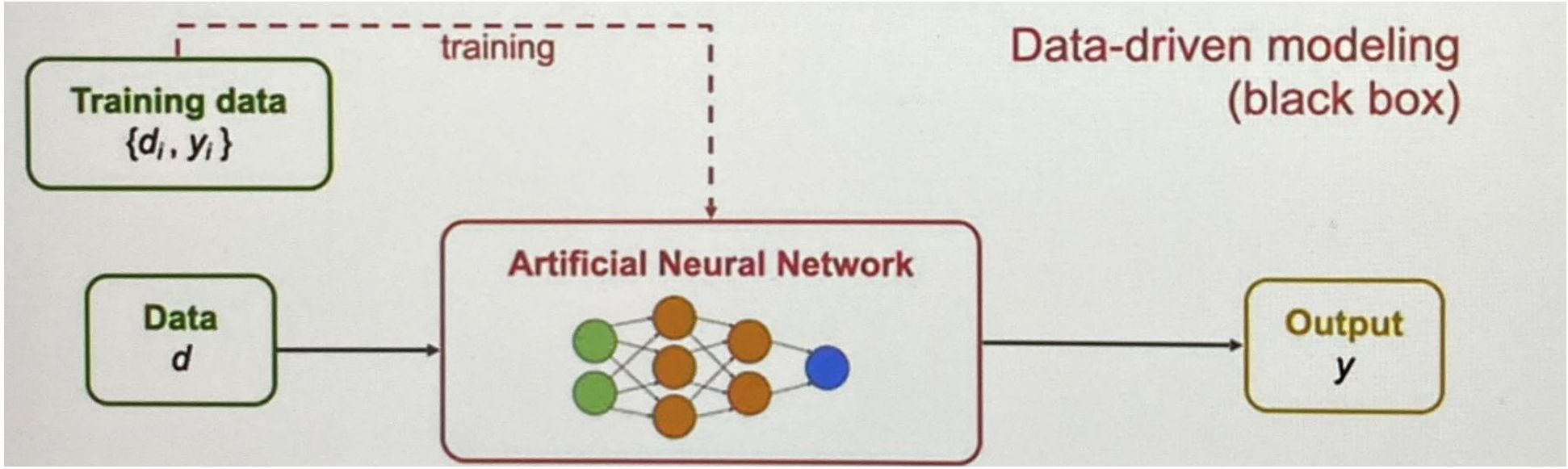
2. AI & ML for Disaster & Risk Assessment and Response

There's increasing work on using AI (including generative models to combine multiple data streams , such as text, imagery, video, sensors) to assess damage, simulate disaster scenarios, prioritize response, or predict vulnerabilities (Raj et al., 2025).

Hazards modeling are essentially based on physics-based approach while a new exploding modeling tool is AI and ML.

PHYSICS-BASED versus DATA-DRIVEN MODELING





Quarteroni (2025)

Key Emerging Topics in Disaster Science

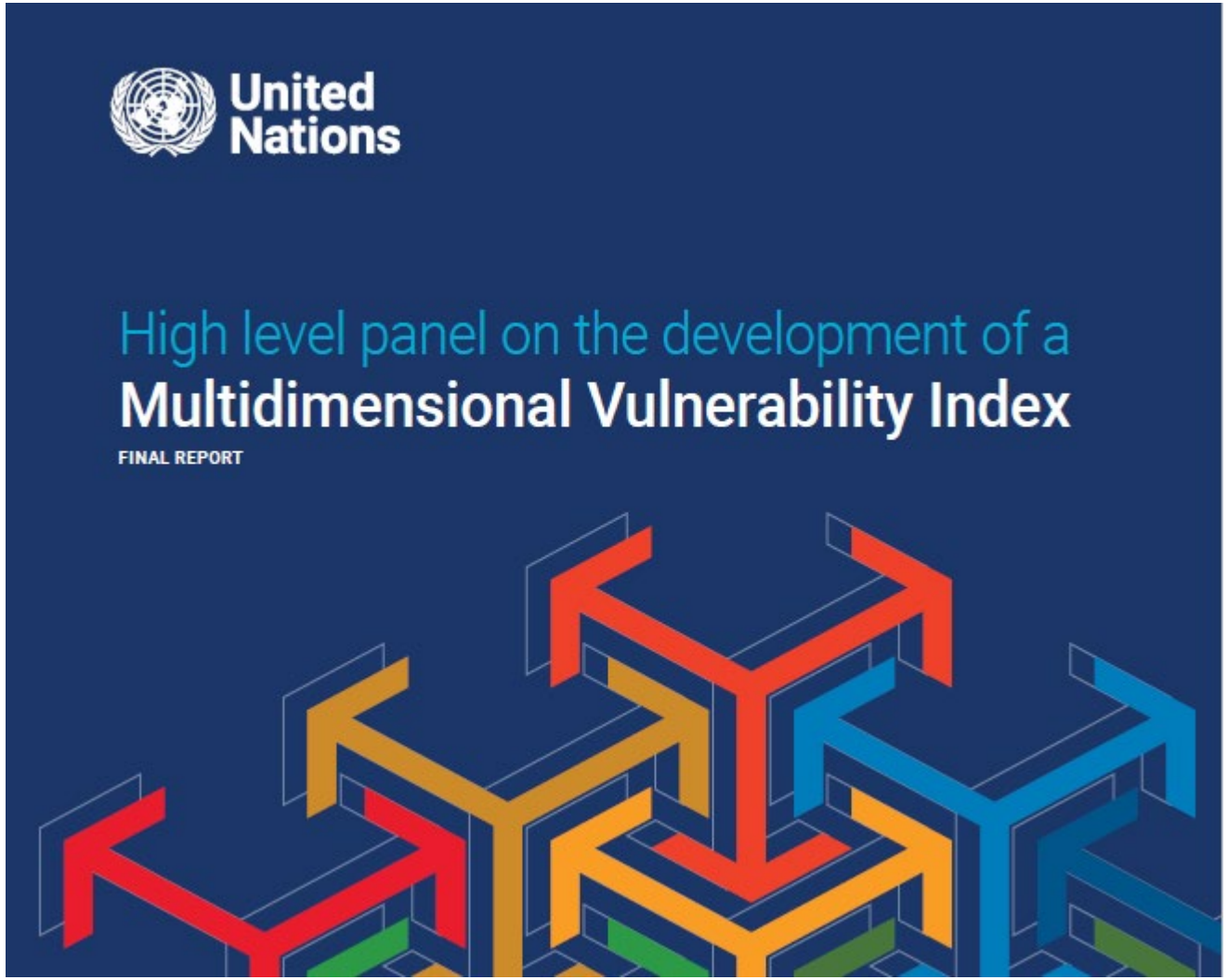
Beyond ***mapping hazards and exposure***, there is growing interest in modelling and monitoring ***pre-*** and ***post-disaster vulnerability*** as it evolves over space and time. For example, AI methods like graph-based variational auto-encoders to integrate satellite data and expert judgments to audit how vulnerability changes after disaster (Dimasaka et al., IDRC 2025).

Tracking vulnerabilities after disasters helps identify and plan critical recovery needs and focus resources effectively as well as develop resilience strategies to reduce future risks.

I would invite the SC to explore possibilities to design

Digital Global Dynamic Risk Model for All

Key Emerging Topics in Disaster Science



"Over the past eighteen months, the Panel has worked to develop an evidence-based and robust quantitative benchmark designed to assess structural vulnerability and lack of resilience across multiple dimensions of sustainable development at the national level. To accompany the index, the Panel has also developed Vulnerability and Resilience Country Profiles (VRCPs) which provide granularity on a country's specific challenges related to vulnerability and resilience."

Key Emerging Topics in Disaster Science

3. Emerging Technologies & Digital Tools

Use of drones, digital twins, remote sensing, real-time monitoring, and other tools for planning/training (WMO, 2023).

- *Drones* capture aerial imagery and data providing critical insights in disaster zones quickly and safely.
- *IoT sensors* monitor environmental conditions and infrastructure status, feeding real-time data for analysis.
- *Real-time monitoring* systems integrate data to improve situational awareness and precise disaster response.

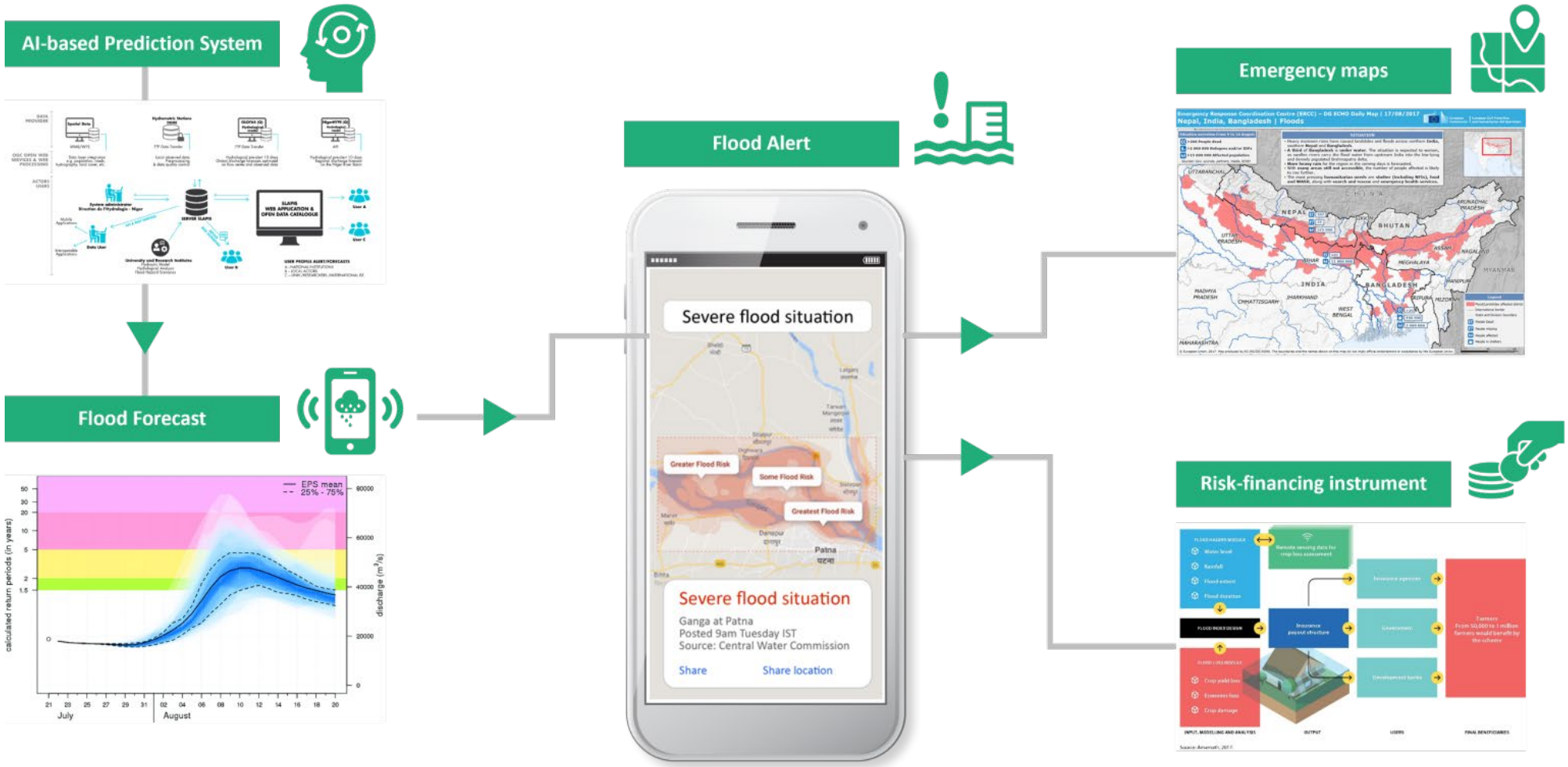
Key Emerging Topics in Disaster Science

3. Emerging Technologies & Digital Tools

Utilizing digital twins, metaverse environments, and remote sensing.

- *Digital twins* create realistic disaster environment models for effective training and scenario planning.
- *Metaverse platforms* (e.g., virtual reality) enable immersive disaster preparedness training and improve coordination among responders.
- *Remote sensing* provides real-time data to enhance accuracy of digital twin simulations and disaster response.

Key Emerging Topics in Disaster Science



The use of IoT sensors along with remote sensing may provide water level data. Drones are being employed to generate images with high spatial resolution for hazard and risk mapping as well as to locate survivors using thermal imaging.

(Source: Giriraj Amarnath, IWMI)

Key Emerging Topics in Disaster Science

4. Intersections with Climate Change, Urbanization & Social Vulnerability

Changing climate patterns (e.g. more extreme rainfall, sea level rise, shifting hazard zones) should be combined with rapid urbanization, population growth, and inequality to monitor changing risk.

Also, it is important to analyze how vulnerability is socially constructed.

Key Emerging Topics in Disaster Science

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Deeper Understanding of Impacts of Climate Change on Hazard Patterns and Exposure

- Climate change causes *more frequent* natural hazards, intensifying risks globally. How frequent?
- Hazards become *more severe* due to climate shifts, leading to higher damage potential. How much severe?
- Changing hazard patterns increase exposure and vulnerability of communities worldwide. *How complex is an interaction between three major components of disaster risk*?

Key Emerging Topics in Disaster Science

AI-generated image

Urbanization, population growth & evolving vulnerabilities

- *Rapid Urban Growth*. Urban areas are expanding quickly, leading to high population densities in cities worldwide.
- *Hazard-Prone Areas*. Many urban populations settle in regions vulnerable to natural hazards, increasing risk exposure.
- *Challenges for Risk Management*. Growing vulnerabilities require improved strategies for managing and mitigating urban risks effectively.

Key Emerging Topics in Disaster Science

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Social Construction of Vulnerability & Inequality

- *Impact of Poverty.* Poverty increases vulnerability by limiting resources needed for disaster preparedness and recovery.
- *Marginalization Effects*. Marginalized groups often face greater challenges accessing aid and support during disasters.
- *Inequality's Role.* Social inequality shapes recovery processes, with disadvantaged groups experiencing slower rebuilding and support.

Key Emerging Topics in Disaster Science

5. Damage & Loss Data

There is an ongoing need for better, more consistent data about disaster losses (both human and economic), damage patterns, especially for less studied regions. This helps with modelling, risk assessment, and policy.

Some data sources

- Satellite images for evaluating disaster-affected areas.
- Social media platforms for real-time reports and eyewitness accounts to enhance damage assessments.
- Sensors-collected environmental data for detailed assessment of disaster impacts.
- Historical data for predicting current disaster assessments.

Key Emerging Topics in Disaster Science

6. Preparedness & Forecast-Based Financing

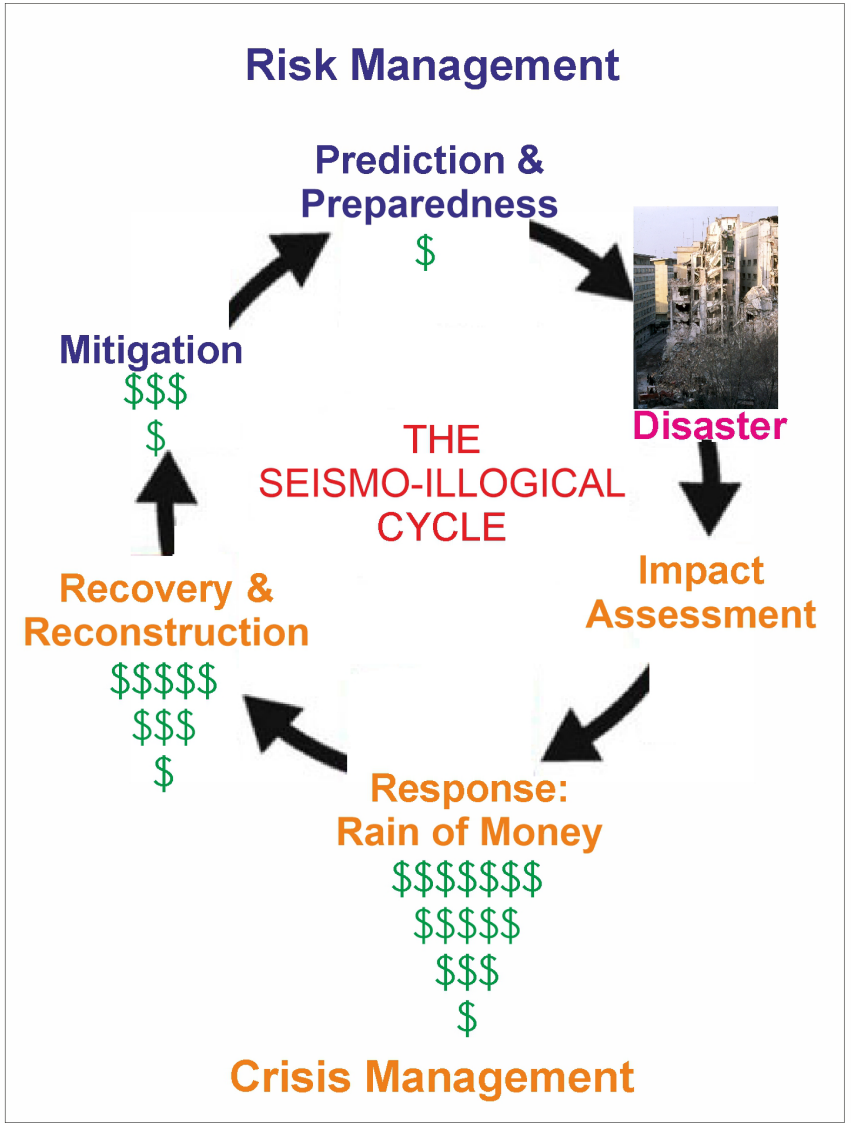
Moving disaster risk management upstream: taking actions before a disaster fully unfolds.

This includes anticipatory financing, extreme event forecasting, early warnings, preparedness, and public awareness.

Key Emerging Topics in Disaster Science

"The societal costs and benefits must be re-examined as well as the efforts to improve public safety. If about 5 to 10% of the funds, necessary for recovery and rehabilitation after a disaster, would be spent to mitigate an anticipated event, it could in effect save lives, constructions, and other resources" – Ismail-Zadeh and Takeuchi (2007).

The "seismo-illogical cycle" (can be any type of hazards) means that a large investment is made when a disaster occurs and the financing decreases till next disaster. If a seismic cycle is marked by an *increase* of tectonic stresses toward an earthquake (stress drop), the "seismo-illogical cycle" is characterised by a *decrease* of funding toward the next large seismic event (Ismail-Zadeh, 2009)



Key Emerging Topics in Disaster Science

7. Disaster Risk Communication

How to translate warning or risk information so that it is actionable, reaches marginalized populations, and accounts for social, cultural, economic barriers.

Also, more attention to local knowledge, participatory approaches.

Key Emerging Topics in Disaster Science

Translating warnings into actionable messages.

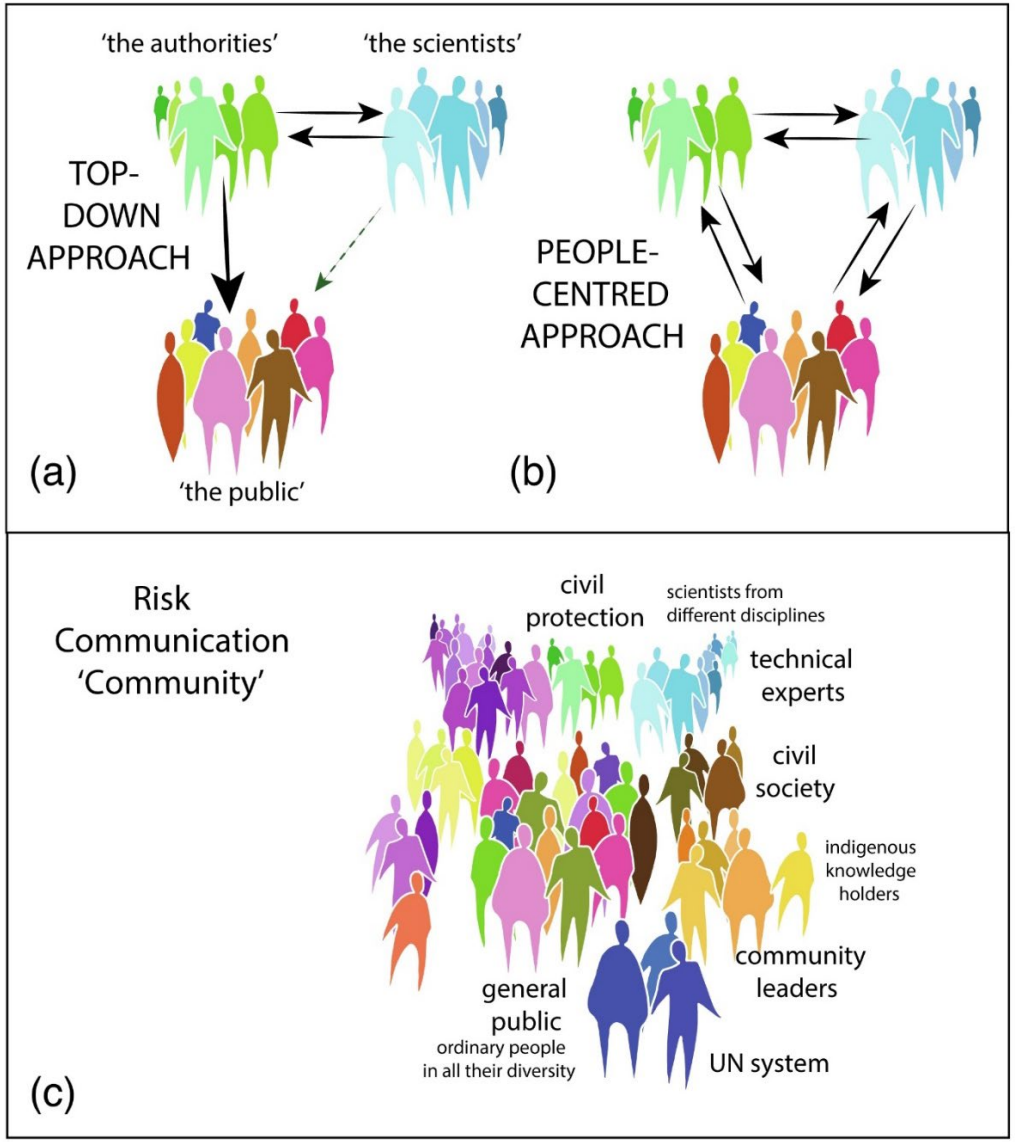
- Messages must be *clear and easily understood* to prompt immediate protective actions.
- Tailoring messages to *cultural contexts* improves community trust and response effectiveness.
- *Effective messaging* motivates individuals to *act promptly during emergencies*.

Reaching marginalized populations

- Overcoming *language differences* is crucial for clear risk communication to marginalized populations.
- Ensuring communication methods are *accessible to people with disabilities* enhances information reach.
- *Establishing trust* encourages marginalized groups to receive and act on important risk information.

Key Emerging Topics in Disaster Science

A multi-way disaster risk communication should encompass all relevant stakeholders involved in risk management and serve as an integral component of the collaborative efforts and outcomes of the stakeholders (Cutter et al., 2015; Steward, 2024).



(Steward, 2024)

Key Emerging Topics in Disaster Science

8. Education & Capacity Building

Preparing future researchers and practitioners in DRR and climate change adaptation through inter- and trans-disciplinary training, integrating critical thinking, co-learning with communities and practitioners.

Simulations and training modules enhance skills and knowledge for effective disaster response.

Key Emerging Topics in Disaster Science

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Integrating Disaster Risk Topics in Education

- *Early Awareness Building*. Introducing disaster risk topics early helps children understand potential hazards and safety measures.
- *Curriculum Integration*. Embedding disaster risk reduction into school curricula ensures consistent knowledge development across grades.
- *Foundational Knowledge*. Formal education builds foundational skills to prepare students for responding to emergencies effectively.
- New curricula should incorporate *adaptive learning methods* to meet evolving disaster management needs.
- *Continuous learning programs* help professionals stay updated with latest technologies and disaster strategies.

Frontier Research Questions

- **How can we effectively model multi-hazard risk including cascading, compounding, and interacting hazards? How do *vulnerabilities and exposures* shift in real time across hazards?** For example, “the starting point should be a specific sustainability challenge, rather than an individual hazard or sector, and trade-offs and synergies are examined across sectors, regions, and hazards” (Ward et al., NHESS 2022)

- **How to integrate *dynamic*, high-resolution exposure and vulnerability data into early warning systems (EWS) and risk assessments?** “The maps change with time, specifically in big cities and coastal regions, and there is a need to proceed to georisk monitoring. Therefore, research on time-dependent hazard, vulnerability and risk is essential to update periodically natural hazard and risk maps.” (Ismail-Zadeh and Takeuchi, 2007).

- **How to move from hazard-based to *impact-based* forecasting and warning systems in diverse socio-cultural contexts?** *Impact-based warnings* try to tell not just what hazard will happen, but what effects (e.g. damage, displacement, disruption) might occur, and what actions people should take. How to format and deliver those so that they are trusted, understood, and actionable? Significant gaps persist in understanding the interplay between the scientific, social, and organizational elements underpinning effective risk management (Pescaroli et al., Front Comm,2025)

Frontier Research Questions

- **Role of AI, Generative Models, and Human-AI Collaboration in Disaster Science.** How to develop AI tools that are robust, transparent, explainable, and safe in disaster contexts (where stakes are high, and data may be incomplete or noisy)? What are best practices for human-AI teaming (decision support), especially when human actors have varying levels of technical literacy, different decision frameworks, and time pressure?

- **How to ensure Science-Policy-Practice interfaces are effective, especially under conditions of uncertainty, scale, and asymmetric power?** What institutional mechanisms, governance arrangements, or social structures help ensure that scientific insights inform policy and disaster risk management practices? How to reconcile different knowledge types (e.g., scientific, local, indigenous) and address the strategic and institutional gaps that often block implementation? (Albriset al., IJDRS, 2020)

- **Standards, data interoperability, and measurement for risk reduction, resilience, and losses.** What standards, metrics, and data infrastructure are needed so we can reliably compare losses, exposures, vulnerabilities across countries and disasters? How to ensure data is timely, accurate, accessible, and used — including remote sensing, citizen science, IoT, and other emerging sources?

Frontier Research Questions

- **Sustainability, resilience trade-offs, and transformational adaptation under climate change.** As climate change intensifies hazards, what adaptation strategies (structural, nature-based, institutional) are robust, and what trade-offs do they entail (cost, environmental impacts, social equity)? How to foster *transformational* change — not just incremental adaptation — in governance, land use, infrastructure, social norms?

- **Community-level resilience dynamics and recovery paths.** How do social networks, local institutions, and community practices contribute to resilience and recovery? How do these dynamics evolve through the recovery process? (e.g., network dynamics of community resilience & recovery; Chia-Fu Liu and Mostafavi, 2025). What interventions (policy, governance, resource allocation) best support equitable recovery — not just rebuilding, but improving resilience?

- **Social behavior in risk communication and community resilience.** How to design risk communication (warnings, forecasts, advice) that works for marginalized or vulnerable populations, who may have lower access, different languages, cultural templates, or trust dynamics? What behavioral models best predict how people perceive risk, how they respond (or do not respond), especially under complex messages or conflicting information?

The END

Thank You!