2018

Understanding Risk

Disrupt. Communicate. Influence.

Proceedings from the 2018 UR Forum

This publication is made up of a series of submissions from session leads of the 2018 Understanding Risk Forum. These submissions were compiled by the Global Facility for Disaster Reduction and Recovery (GFDRR). The content and findings of this publication do not reflect the views of GFDRR and the World Bank Group.

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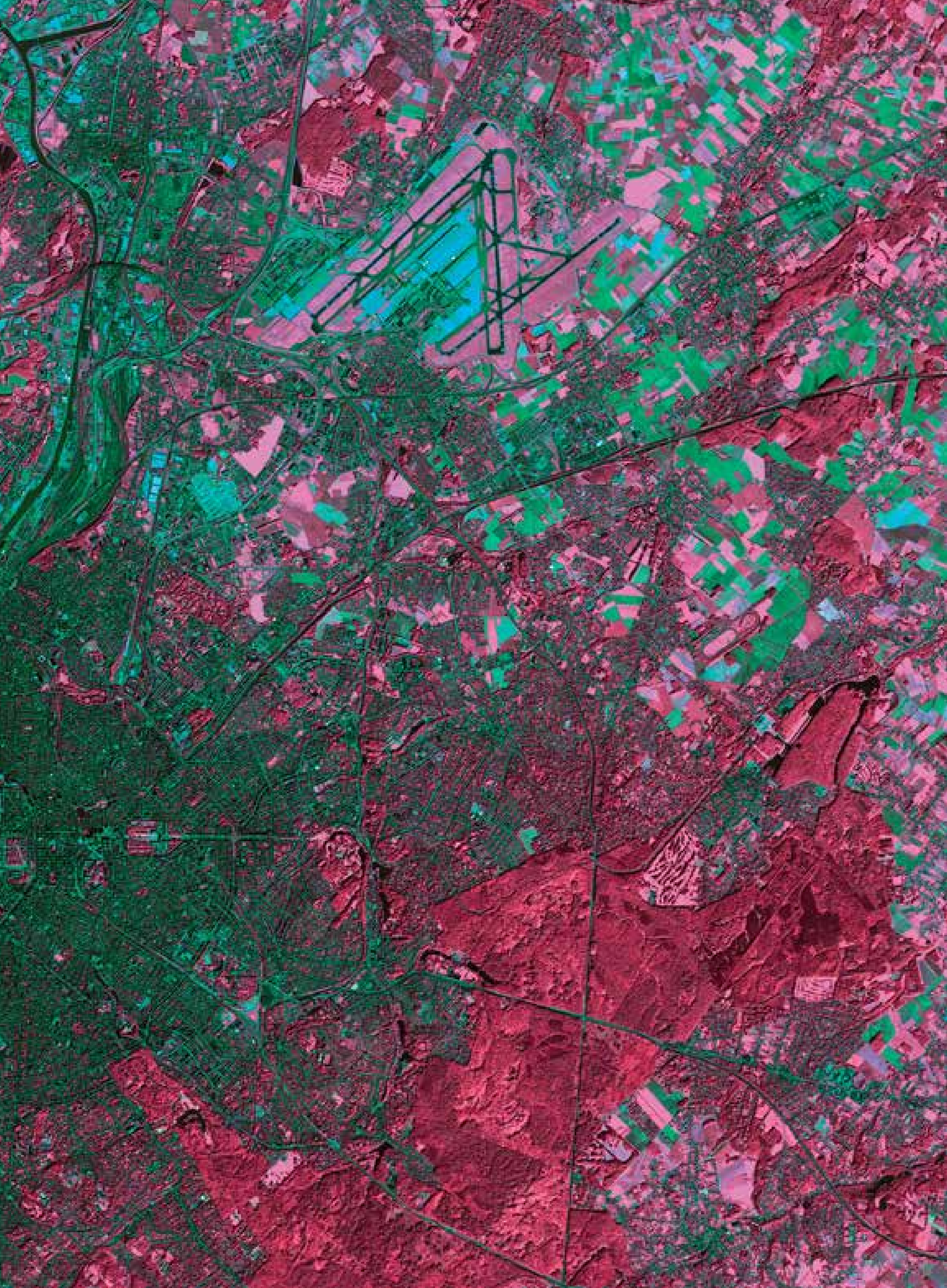
False-color image of central Belgium, capturing the capital city of Brussels (right). Photo: ESA.



Contents

iv Acknowledgments
vi Abbreviations
ix Overview

Assess.

2 Must Disasters Cascade like Dominoes?

8 Risk Assessments in Infrastructure Planning: Learning from Failure

14 Assessing and Communicating Risk to Cultural Heritage: The Future of Preserving the Past

20 Assessing Urban Flood Risk: Going with the Flow

26 Side event City Coastal Resilience: How Would YOU Protect Africa's Coastal Cities from Climate Change?

28 Side event Understanding Disaster Risk in Situations of Fragility, Conflict, and Violence

Disrupt.

32 Plenary Resilience Dialogue: Artificial Intelligence in Disaster Risk Management—Could AI Transform DRM?

36 The Future of Risk Modeling

42 Advances in Drone Technology: Flying Robots

48 The Root of Irrational Risk Decisions: How to Manage Human Cognitive Biases

54 A Conversation on Geoengineering: Altering the Planet, Envisioning Risk Financing Mechanisms

54 Cyber Risk in Light of Technological Innovation

58 Side event Green Walls: Using Nature to Manage Nature's Risks

60 Side event Is Migration Our Future? People in the Front Line of a Changing World

Communicate.

72 Plenary UR Story: Narrative and Risk

76 The Risk Information Value Chain: Data, Science, Narrative, and Action

74 Communicating Volcanic Risk: Lava, Eruptions, and Uncertainty

90 A Picture Is Worth a Thousand Actions: Communicating Earth Observation Data

96 Selecting the Best Satellite-Derived Risk Tool: Mining the Sky for Decision Making

102 Communicating Risk: Approaches for Parametric Insurance

108 Side event The Interdisciplinary Pressure Cooker Event on Risk Communication: Supporting the Next Generation of Risk Communication Professionals

110 Side event Lights! Camera! Risk-Informed Action!: Making and Using Videos for Effective Communication of Risks and Good Practices to Address Them

Influence.

116 Plenary Communicating Urgency: Using Music to Convey Climate Change Data and Help Scientists Deliver the Message

120 Early Warning for Early Action: Forewarned and Forearmed

126 Small islands: Innovations in Understanding Risk

132 Learning from Mexico's Experience, 1985 to 2017

138 Public Policies for Disaster Risk Management in Mexico: Challenges in Implementing GIRD

144 Side event Reaching the Last Mile: Challenges and Lessons from Early Warning Systems

146 Side event Risk-Informed Decision Making for Sustainable Development

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Abbreviations

ACA	Agency for Cultural Affairs
AGI	artificial general intelligence
AI	artificial intelligence
ASI	artificial specialized intelligence
CCRIF-SPC	Caribbean Catastrophe Risk Insurance Facility
CENAPRED	National Center for Disaster Prevention (Mexico)
CESM	Community Earth System Model
CIESIN	Center for International Earth Science Information Network
CIS	Climate Information Services
CISRI	Climate Information Services Research Initiative
CityCORE	City Coastal Resilience in Africa
CMP	ClimateMusic Project
CREWS	Climate Risk and Early Warning Systems
DAPP	Dynamic Adaptive Policy Pathways
DL	deep learning
DRF	disaster risk financing
DRM	disaster risk management
EO	Earth observation
FCV	fragility, conflict, and violence
GDP	gross domestic product
GFDRR	Global Facility for Disaster Reduction and Recovery
GIRD	Comprehensive Disaster Risk Management
GIZ	German Agency for International Cooperation
INCD	Israel National Cyber Directorate
IoT	Internet of Things
IFRC	International Federation of Red Cross and Red Crescent Societies

IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society-Columbia University
LISCoAsT	Large Scale Integrated Sea-level and Coastal Assessment Tool
ML	machine learning
MMA	Monterrey Metropolitan Area
MSF	Médecins Sans Frontières
NBS	nature-based solutions
NEMO	National Emergency Management Office (Tonga)
NERC	Natural Environment Research Council
NMHS	national meteorological and hydrological service
ODI	Overseas Development Institute
PCRAFI	Pacific Catastrophe Risk Assessment and Financing Initiative
PHIVOLCS	Philippine Institute of Volcanology and Seismology
RCP	Representative Concentration Pathway
SIDS	Small Island Developing States
SINAPROC	National System of Civil Protection (Mexico)
SSP	Shared Socioeconomic Pathways
TE2100	Thames Estuary 2100
TU Delft	Delft University of Technology
UAV	unmanned aerial vehicle
UNAM	National Autonomous University of Mexico
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISDR	United Nations Office for Disaster Risk Reduction
WYN	Water Youth Network

5 days in CDMX

23
technical sessions

57
side events

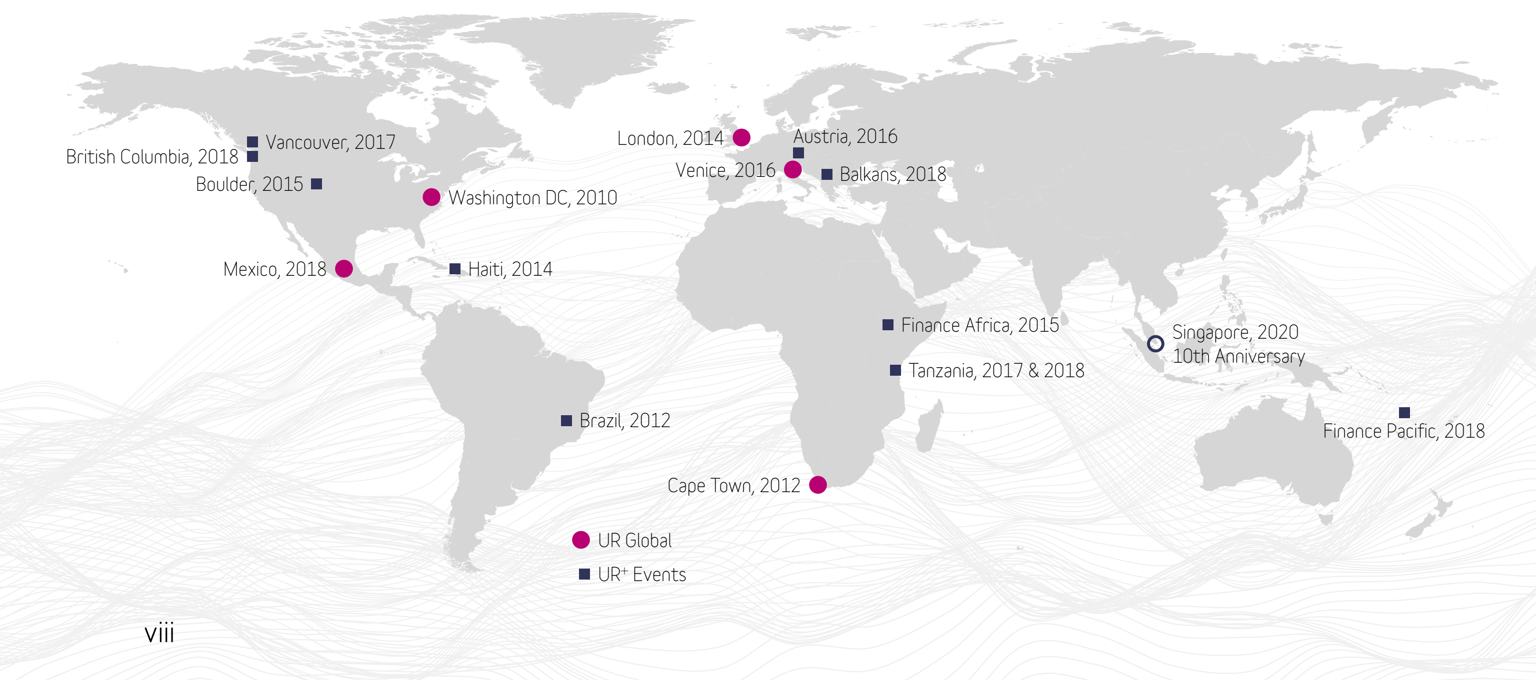
1,060
attendees

5,000+
meetings

101
countries represented

550+
organizations represented

while at UR
85
earthquakes > 4.5M worldwide



Overview

The Understanding Risk (UR) community was born in 2010 out of the recognition that disaster risk assessment and identification were activities that cut across sectors and industries. What began with just five founding partners has grown into a community of over 8,000 experts and practitioners interested and active in the creation, communication, and use of disaster risk information. This network has inspired innovation by sharing and applying best practices, developing technological solutions, and enabling cross-sector partnerships.

This vibrant UR community meets every two years, bringing together a diverse group of people from the private, public, nonprofit, technology, research, academic, and financial sectors. Every iteration of the UR Forum has produced new ideas and partnerships that have improved risk assessments and the communication of risk information, helping to integrate them into policy and development planning. UR2018 was held in Mexico City, Mexico, from May 14 to May 18, 2018, under the theme *Disrupt. Communicate. Influence.*

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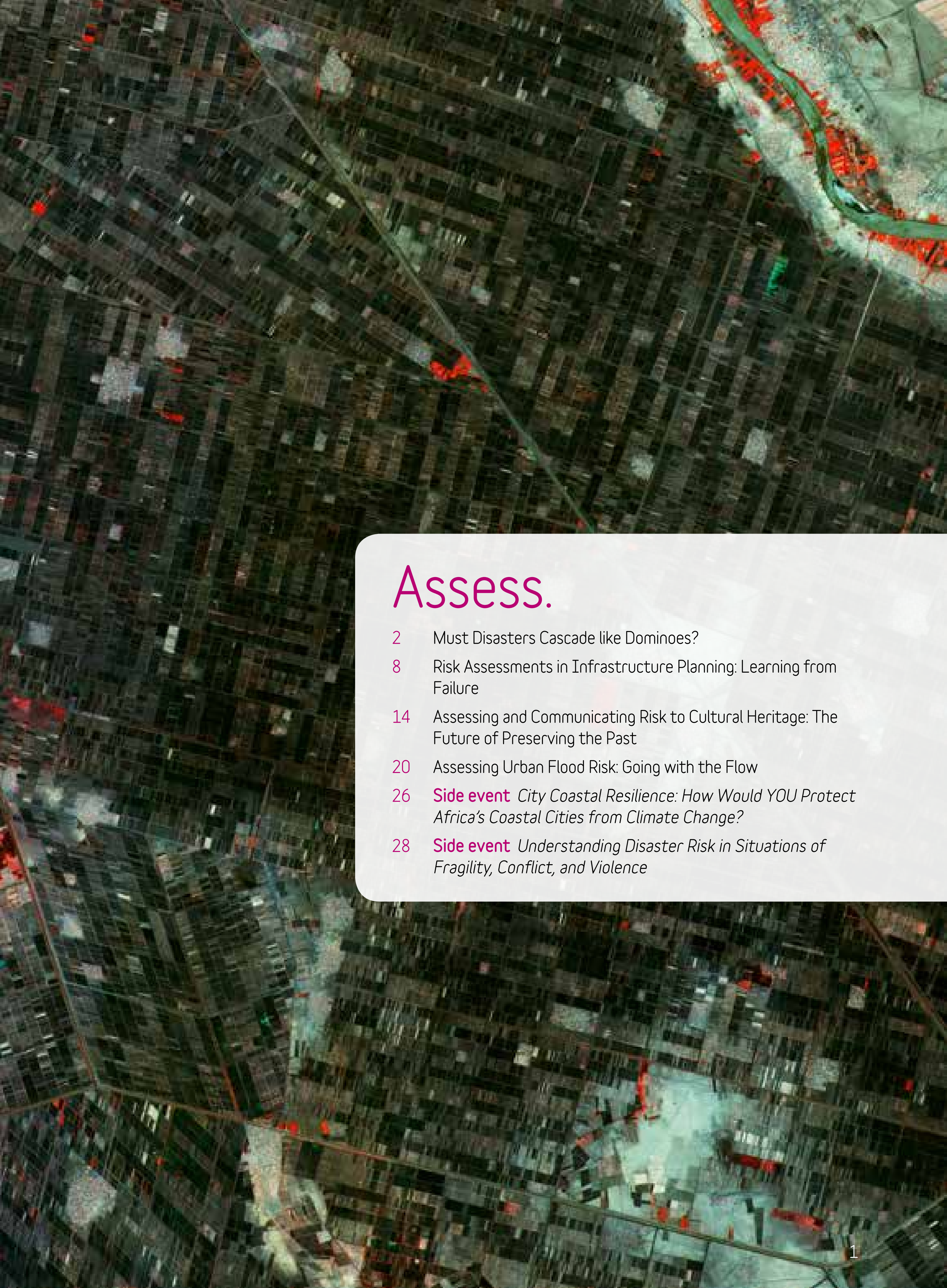

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Must Disasters Cascade Like Dominoes?

Resilience in its highest form entails the ability to prevent disasters from cascading into multi-disaster catastrophes. Although some destruction and misery are inevitable in a storm or earthquake, much is preventable. Too often, a single inevitable event triggers preventable repercussions that expand the breadth, duration, and size of adverse consequences. These consequences come in the form of preventable business disruption, displacement, economic distress, social anguish, hunger, thirst, and disease.

Our challenge is first to learn from cascading disasters and then to engineer property solutions and influence human behavior so that the first few dominoes to fall are the last. Our ability to replace and reposition the fallen dominoes quickly is also important. The single-domino experience is the apotheosis of disaster risk management.

1906 San Francisco Fire that was caused by a M7.9 earthquake. Photo: Arnold Genthe/Wikimedia Commons.

Background

In our UR2018 session, we examined several cascading disasters, real and hypothetical, and the tremendous resulting costs. We wanted participants to understand cascading events through the lenses of people, communities, operations, the environment, supply chains, and investment. These six elements form a framework for analyzing a region's resilience to cascading events. We also wanted to help participants do the following:

- Develop more effective strategies to prevent cascading events
- Minimize the impact of inevitable events
- Invest more effectively in resilience
- Successfully rebound from disaster

Case Studies

We have included three of the disaster scenarios explored at the session. One is a hypothetical warehouse fire, and two are very real disasters: the 2005 Buncefield oil depot fire and the 2011 Tohoku earthquake.

The shaken warehouse

Disasters can cascade into catastrophe in many ways. Sometimes events start innocuously and in other cases, the event is a catastrophe from the outset. Our first case lies somewhere in the middle.

Imagine you are a manufacturer of cell phone components containing rare earth elements. Your warehouse—filled with delicate and expensive parts—is warmed by a gas-powered space heater. When an earthquake strikes, the building remains standing. The carefully stacked parts wobble on the shelves, but none fall.

However, the rumbling earth has broken the rigid gas line, and gas leaks into the facility. The space heater, now disconnected from the gas main, topples to the ground, igniting the leaking gas and resulting in a fire that burns down the warehouse. The earthquake was inevitable but the gas line break was not. The fire didn't have to occur. It was cascading effect number one, the first of many.

Your employees struggle with the earthquake's impact on their homes and families. Their place of work has been destroyed, necessitating additional travel to another facility with more difficult working conditions. Some may take another job closer to home.

To replace the parts lost in the fire, you incur tremendous cost to mine new raw materials, process them into useful alloys, and fabricate them into replacement components. There is also a broadly recognized environmental cost to extracting the elements—and, hence, a political cost given the ecological value of the minerals. Because the components were destroyed, business operations cease for weeks. That means the original equipment manufacturers are angry, and revenue has dried up. More resilient competitors seize your market share. The loss of employees and market share may be irreversible.

Buncefield

Real-life incidents similar to the warehouse example have directly affected entire industries. A case in point is the 2005 explosion at the Buncefield oil depot north of London. The ensuing fire—Europe's largest ever in peacetime—occupied 1,000 firefighters for five days, thereby jeopardizing fire protection in the rest of the region.

Although no one was killed, the entire region was affected. The local Dacorum Borough Council reported that many people lost their homes; 200 people—mostly firefighters—attended local hospitals, and 45 sustained injuries; 60 children needed counseling; and 9,500 employees were displaced from 92 businesses. Two years after the event, a quarter of affected businesses were still struggling to recover.

Our challenge is first to learn from cascading disasters and then to engineer property solutions and influence human behavior so that the first few dominoes to fall are the last.

The Buncefield fire had a major impact on the environment. Residents were faced with dense black smoke and contaminated

Buncefield Fire. Photo: Aligibbs.

groundwater. According to government and media reports, officials contended with 50 tons of contaminated waste and extensive debris from buildings; some 500 tankers took more than five weeks to remove the firefighting foam and water from the site.

The local business impact was estimated at £1 billion and the regional impact at £5 billion, with reverberations extending across the United Kingdom and its supply chains (Hiles 2014). By its own report, the Buncefield oil depot supplied 8 percent of the nation's overall fuel and 40 percent of the aviation fuel for Heathrow Airport. The loss of fuel and warehouse space resulting from the explosion affected air travel, food supplies, and retail trade.

Tohoku and Fukushima

The 2011 Tohoku earthquake triggered the quintessential toppling of dominoes, and they are still falling.

Centered off the coast of Japan east of Tohoku, the magnitude 9 quake touched off what has been called the costliest disaster in history. Two tectonic plates slid more than 150 feet, shaking the earth for six minutes, spawning numerous aftershocks, shifting the island of Honshu eastward by eight feet, and dropping sections of shoreline by two feet.

The second domino (also inevitable) was even more destructive: the quake generated a tsunami with 100-foot-plus waves that roared as far as six miles inland and flooded 217 square miles. The waves destroyed seawalls, toppled three-story buildings, and swamped the Fukushima Daiichi Nuclear Power Plant. The destruction resulted in a failure of the plant's cooling systems and a meltdown. Radioactive debris, swept out to sea, has reached as far as Canada and California. Approximately 80,000 of the nearly half million evacuees were still living in temporary housing as of late 2017 (Reconstruction Agency 2017).

Japan estimated the rebuilding cost at more than US$300 billion. More than 15,000 people died, and 2,500 were still missing as of 2017.

Challenges

In every case, there were opportunities to manage risk before the disruption and mitigate the cascading consequences. Yet one of risk management's major challenges is convincing people—officials, executives, staffers, and front-line workers—that mitigating risk is worth the effort and cost.

A sign indicating an event, tsunami, a cascading product of earthquake.

In our warehouse example, the cascading impact from earthquake to large fire could have been interrupted by simple risk mitigation solutions: a flexible gas line connection equipped with an automatic seismic gas shutoff valve in a warehouse fully equipped with adequately braced automatic fire sprinklers. Resilience was possible with the help of a modest plumbing job, which could have been done at a fraction of the cost of the cascading events.

Buncefield provides an object lesson in cascading causes as well as effects. What initially ignited was fuel vapor from an overfilled tank, made possible when both a fuel-level gauge and automatic overfill shutoff switch failed. There were subsequent secondary and tertiary containment failures and ultimately what one judge (Competent Authority Strategic Management Group, n.d.) called "slackness, inefficiency and a more or less complacent approach to matters of safety."

At Fukushima, the height of the tsunami was a surprise. Although the earthquake shaking did not produce much damage, the tsunami overtopped seawalls designed for smaller waves and knocked out the backup cooling systems, leading to the meltdown. The Japanese government learned from the disaster and has taken steps to harden critical infrastructure and raise awareness of disaster risk.

In every instance, pre-disaster human intervention could have dramatically changed the outcome. When wise property protection investments are made, big returns are common. For example, FM Global analysts looked at the performance of clients' facilities during hurricane Maria in 2017. FM Global client costs associated with wind damage were four times lower than those of other companies, with many back in business within days, not months. These clients protected their businesses from repercussions from a major hurricane loss, such as damage to reputation, market share, and shareholder value.

Recommendations

What can actually prevent dominoes from cascading? The experienced risk managers in our audience had some recommendations:

- Focus on water. Storm-related waves, storm surge, and riverine flooding can devastate private and commercial property. In a fire, sufficient water access and volume are the greatest challenges.
- Beware the wind. When power

lines are blown down, personal safety and businesses are jeopardized.

- Plan for population movement. Evacuating populations out of harm's way remains a significant challenge.
- Strengthen zoning and building codes. Zoning should discourage thick settlement along the coast. Building codes should require fire protection and seismic resistance, so that after a hazard event people have homes to return to and offices where they can keep earning wages.
- Plan communities well. Sound urban planning—buffering industrial zones to prevent fire spread, for instance—is paramount.
- Understand the value of mitigation. Preventing civic and business disruption can have far-reaching effects on preserving quality of life and economic prosperity. An insurance policy can't cover the often avoidable loss of reputation, market share, or shareholder value, which can harm a business more than property loss.
- Choose resilience. The return on choosing resilience can be significant. Making the wrong choice can be catastrophic.

Conclusions

Before a disaster strikes, it is critical to estimate potential costs of damage in lives and dollars, and to determine which costs can be avoided by minimizing cascading effects.

The most effective way to prepare for cascading disasters is to learn from past experiences. By identifying which dominoes didn't need to fall, we can take necessary preemptive actions to be more resilient and save lives and livelihoods.

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3D rendering of New Orleans, USA. Photo: Naeblys

Risk Assessments in Infrastructure Planning:

Learning from Failure

Infrastructure investments are capital intensive and often inflexible, and they leave long-lived footprints that affect communities, economies, and ecosystems for decades or even centuries. Good decision-making processes are thus crucial to ensure that as conditions change over time, infrastructure delivers reliable service and does not become a "stranded asset" or increase future risk.

There are many examples of bad decisions around infrastructure projects—decisions that led to huge sunk costs, political tensions, increasing risks, and sometimes catastrophic outcomes, such as the failure of the New Orleans protection system during Hurricane Katrina. With climate change affecting the frequency and intensity of natural hazards, and fast technical progress making some investments obsolete, local governments and utilities tasked with implementing infrastructure projects are experimenting with new approaches that can tackle high uncertainty.

This UR2018 session started with a game that helped the audience understand the challenges of planning for the long term under conditions of deep uncertainty. The main issue highlighted was the danger of selecting long-term investments using traditional tools (such as deterministic cost-benefit analysis) when conditions are changing and large economic interests and lives are at stake. This point was amplified by the three case studies that followed. The three presentations—on Monterrey in Mexico, and Denver and New Orleans in the United States—exposed the challenges that confront cities undertaking infrastructure projects, described various mistakes that led to costly consequences, and showcased new approaches that local governments and utilities are using to plan new investments despite uncertain future conditions.

Case Studies

Water supply for the future in Monterrey Metropolitan Area

With 4.5 million inhabitants, the Monterrey Metropolitan Area (MMA) is the third-largest urban concentration in Mexico. Water for the MMA is supplied from both surface water and groundwater sources, but the San Juan River basin is vulnerable to frequent droughts and floods. In 2017, water demand reached the sustainability limit, estimated at 13.32 m^3/s on average. This demand was projected to double by 2050, but many uncertainties about how urbanization and consumption will change in the next decades make such projections challenging. In addition, climate change makes it more difficult to predict the frequency of future extreme events like droughts.

To plan future infrastructure investments given this uncertainty, the University of Monterrey in collaboration with the RAND Corporation applied a Robust Decision Making approach. They implemented a water allocation model that took into consideration the three reservoirs, the system of wells, and all water users. The methodology allows the selection of the best alternative portfolio for thousands of plausible futures, derived from different scenarios for climatology, groundwater, demand, and desalination costs. Through an optimization routine, the no-regrets alternatives were chosen and grouped into an adaptive plan for the future. In this way, MMA decision makers devised a robust and adaptive solution for the region's water problem, one that preserves 97 percent of reliability and that minimizes costs.

Denver water planning

Denver Water provides treated and raw water for municipal and industrial use to the City and County of Denver as well as several other suburban communities. Denver Water's supply comes primarily from winter snowpack. Water is stored in one of 17 reservoirs, and conveyed to three water treatment plants in a system of streams, tunnels, and pipelines. About 50 percent of the average annual supply comes from the Colorado River basin on the west side of the Continental Divide, and 50 percent comes from the South Platte River basin, east of the divide, where Denver Water and its service area are located.

Denver Water has engaged in integrated water resources planning for over 20 years, but in 2008, six

In the aftermath of Katrina, Louisiana joined its flood protection and land loss functions under a single state authority, the Coastal Protection and Restoration Authority, and mandated the development of a Coastal Master Plan to be refined and updated every five years.

years after the worst single-year drought every experienced by the utility, it adapted its methods and adopted a scenario planning approach. Under this approach, scenarios are crafted around themes that represent plausible future conditions. The scenarios incorporate combinations of assumptions about external drivers of change (e.g., future economy, global greenhouse gas emissions, community values) to evaluate "known unknowns" (e.g., population growth, new technologies, regulations, or climate change) and understand future needs. A key element of the scenario planning process is to challenge embedded assumptions held by staff about the water system and about what the future will look like, and to envision different futures through wide-ranging discussion and exploration of new ideas within the organization.

Protecting New Orleans from flooding

New Orleans is a coastal city on the banks of the Mississippi River, separated from the Gulf of Mexico by 100 km of coastal wetlands and shallow open water bodies. Protection from river flooding is provided by a system of dikes and floodways built and maintained by the U.S. government. With their high rates of deltaic subsidence, New Orleans and the surrounding Mississippi Delta illustrate the future challenges faced by many coastal cities. In 2005, Hurricane Katrina caused the failure of the protection systems surrounding New Orleans. This event brought to light many issues surrounding how the systems had been planned, implemented, and maintained.

More broadly, Katrina forced Louisiana to rethink its coastal protection approach. In the aftermath of Katrina, Louisiana joined its flood protection and land loss functions under a single state authority, the Coastal Protection and Restoration Authority, and mandated the development of a Coastal Master Plan to be refined and updated every five years. The planning process looks 50 years into the future; it considers how degradation (or restoration) of the surrounding wetlands influences the flooding threat in New Orleans, and how the process changes under different scenarios of sea-level rise and subsidence.

One of the challenges to previous coastal protection efforts, which sought a specific level of protection for multiple communities, was that it prioritized projects with very high costs that could not be readily met. This led to protracted construction and made it difficult to integrate new knowledge over time, even when circumstances changed. To address this problem, the Louisiana Coastal Master Plan uses a cost-constrained approach that identifies the most cost-effective projects to pursue given an ambitious (but not out of the question) funding level for all protection projects ($25 billion). Scientific analyses are used to predict future coastal conditions and project benefits based on different assumptions about sea-level rise, subsidence, and other key external drivers. Because the plan is updated every five years, new knowledge can be incorporated and used to determine (1) which projects should be pursued in which areas, (2) what level of protection should be provided, and (3) whether the approach should be structural or nonstructural. The effect of coastal wetland dynamics can also be considered. Such an analysis can show the extent to which wetland restoration can lower flooding levels and how wetland self-adjustment to sea-level rise may offset some of the effects of climate change on flood risk.

Importantly, the 2017 Coastal Master Plan seeks not to eliminate flood risk but to identify a cost-effective path forward, while also paying attention to residents in flood-prone areas and to the residual risk that will remain even after implementation.

Recommendations

To improve decision making in infrastructure planning, the usual decision-making process should be framed and organized differently. Using an integrated model (which can be very simple or very sophisticated) run hundreds or thousands of times, scenario exploration techniques can identify the combinations of factors—climatic, social, or economic—that could create vulnerabilities for the investment plan and can explore all the associated uncertainties and threats.

The complexity of the model chosen depends on the time and budget available, but also on the potential for catastrophic outcomes. Where models are not available or data are scarce, analysts and stakeholders can begin by brainstorming possible surprises or bottlenecks that will hamper a project's success. This step should take place before the detailed engineering design study and the economic analysis and should aim to identify the threats on which those studies would focus. Carrying out this step would naturally require multidisciplinary teams that included social scientists like political scientists or economists.

A decision process that starts by simultaneously testing an infrastructure plan against various sources of uncertainty is particularly attractive for developing countries, given the amount of infrastructure they have yet to build and the pace and magnitude of the changes to come. Developing countries face huge risks of social disruption and economic stalling if they ignore future changes—not only climate changes, but also technological disruptions, possible financial turmoil, and the distributional impacts of development policies. The tools for developing infrastructure that is resilient to uncertainty exist, and they are now available and accessible to all. It is our role as analysts to mainstream them in the decision-making process, and as practitioners to create the right institutional context to ensure they contribute to better decisions and more resilient development.

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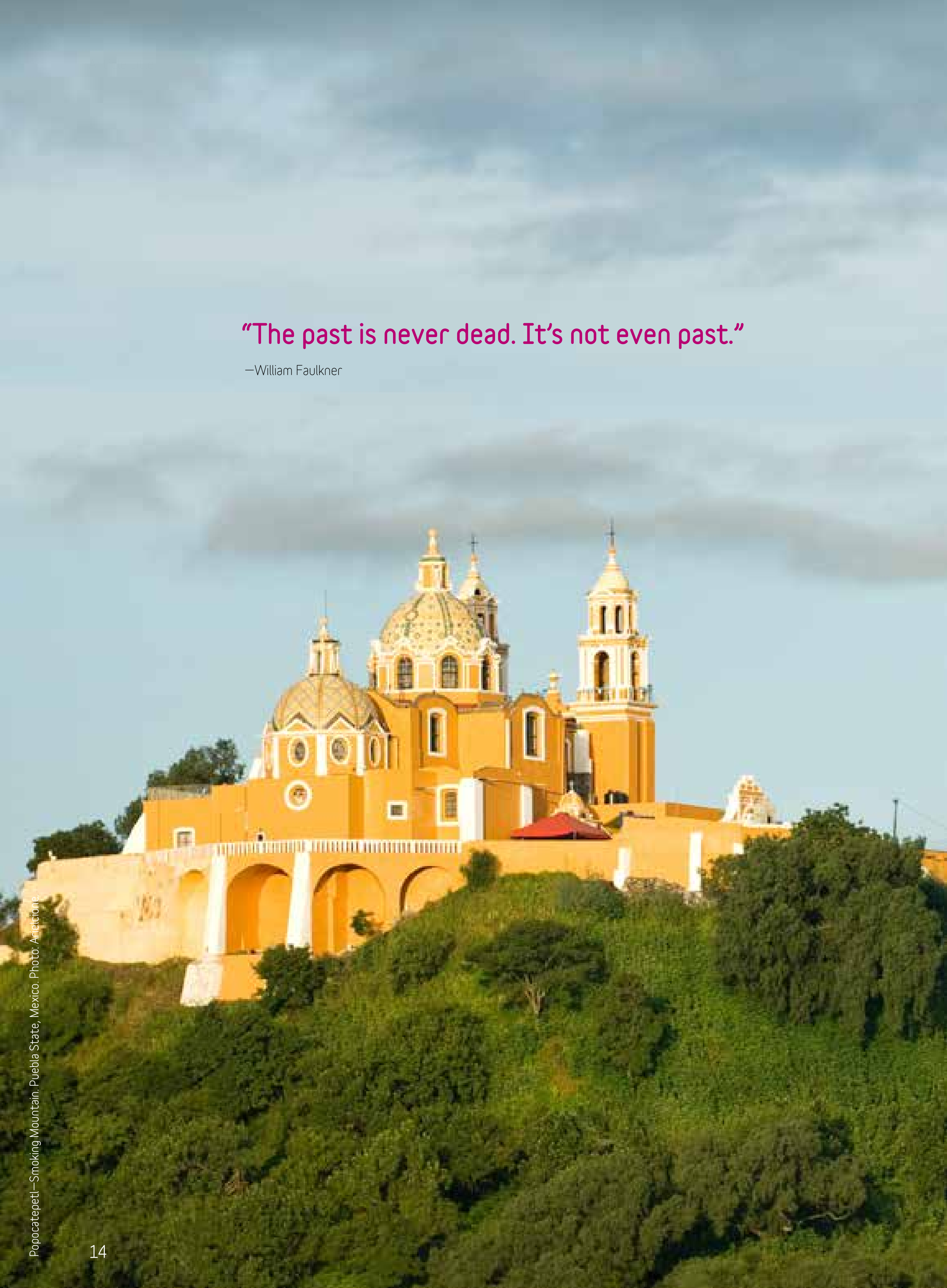
A decision process that starts by simultaneously testing an infrastructure plan against various sources of uncertainty is particularly attractive for developing countries, given the amount of infrastructure they have yet to build and the pace and magnitude of the changes to come.

"Such a joy to be part of an event deliberately designed to make us feel like something special is all around us: beauty, originality, meaning."



"The past is never dead. It's not even past."

—William Faulkner

Popocatepetl—Smoking Mountain. Puebla State, Mexico. Photo: Arielcione.

Assessing and Communicating Risk to Cultural Heritage:

The Future of Preserving the Past

Recent earthquakes—in Mexico in 2017, Italy and Myanmar in 2016, and Nepal in 2015—have demonstrated that our treasures from the past aren't safe. Earthquakes, floods, hurricanes, landslides, and fires threaten treasured heritage worldwide.

Cultural heritage is not just about monuments or traditions, but also about the people whose identity is bound up with the heritage. It is important to reduce irreplaceable losses and manage the economic repercussions of the losses that do occur, including effects on local economies, tourism, and livelihoods.

After the M7.1 earthquake in Mexico in 2017, 1,847 heritage building were damaged, including 351 historic monuments, 14 museums, and 8 archaeological areas—representing nearly 20 percent of overall economic losses.[1] As Giovanni Boccardi of UNESCO (United Nations Educational, Scientific and Cultural Organization) has pointed out, disaster risk is often not given sufficient attention by heritage managers: of the 845 cultural properties on the World Heritage List, very few have a disaster component in their conservation and management plans. According to UNESCO analysis undertaken in 2012, more than one-third of World Heritage properties had not conducted essential risk identification work, and another third had identified risks but not yet started mitigation measures. Only 10 percent had completed a risk preparedness plan.

From the disaster risk management (DRM) perspective, risk to cultural heritage has proven a challenge to identify and manage. Cultural heritage varies in every country in its scope and location, and its connection to human culture can make assigning economic value to such properties controversial or misleading. Ancient structures also often respond differently to hazards than newer buildings, so disaster risk managers need to understand historical techniques and materials, as well as consider previous interventions that might have increased vulnerability and therefore risk.

In most countries, the disciplines of DRM and cultural heritage preservation lack dedicated mechanisms to promote cooperative work. Thus the first step in protecting cultural heritage sites from disasters is connecting professionals from different disciplines and agencies so they can better understand the risk heritage sites face.

Case Study: Puebla, Mexico

The city of Puebla, founded in 1531, became a UNESCO World Heritage Site in 1987.[2] The site has 2,619 monuments that illustrate the city's evolution from the tradition of the 16th century to the emerging modernity of the 19th century. In the last 100 years, Puebla has faced at least 15 earthquakes of magnitude 7.0 or greater, including the M7.1 earthquake of September 2017. Nine people lost their lives and 21 were injured in that event, and many historical monuments, including museums and religious buildings, suffered significant damage.

Following the earthquake, Puebla's mayor, Luis Banck, activated the city's emergency response fund in order to rescue and aid city residents, protect the city's heritage, and promote economic recovery. Volunteers were mobilized to remove debris and gather emergency supplies, but also to provide support during the restoration phase. To promote economic recovery, the city sought to ensure that cultural heritage was integrated into the planning. Officials worked with the UNESCO Office in Mexico, led by resident representative Nuria Sanz, to engage international expertise and support. The goal was to ensure that timely post-earthquake assessments were conducted (see figure 1) and that key repairs—for example, of the Casa de Alfeñique, which dates back to the 18th century—were carried out appropriately (figure 2).

Using these assessments and its own data, the city developed a map to identify current risks to cultural heritage sites, based on the damage to buildings and their facades during the earthquake (figure 3). The city is now using this map to prioritize its interventions and promote economic recovery.

Case Study: Japan's National Risk Assessment of Cultural Heritage

Japan is known both for its rich cultural heritage and hazard-prone location; disasters are part of its history and culture. Under the Disaster Basic Law, national and local authorities are required to formulate disaster management plans, including the collection and sharing of information such as hazards maps.

From 2009 to 2015, the Agency

1 The estimate is according to the National Institute of Anthropology and History (NIAH) and UNESCO, Mexico City.

2 UNESCO, "Historic Centre of Puebla," https://whc.unesco.org/en/list/416.

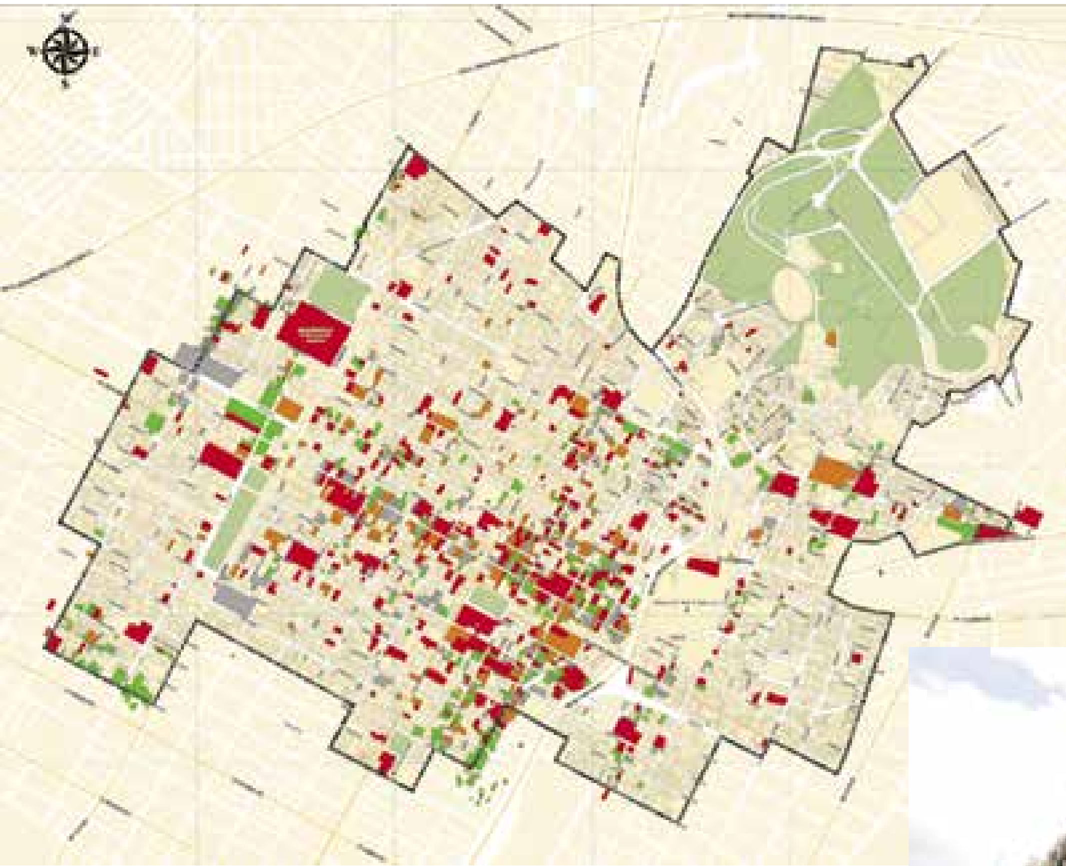


Figure 1. Assessment of monuments based on damage incurred.

Source: Luna Vanessa Silva Muñoz and City of Puebla.

Figure 2. Post-earthquake stabilization of Casa de Alfeñique in Puebla.

Photo: © Carlos Ramírez.

Figure 3. Risk map of cultural heritage in City of Puebla.

Source: Luna Vanessa Silva Muñoz and City of Puebla.

Box 1. The Disaster Imagination Game (DIG)

The DIG methodology was developed in Japan to help local communities understand and communicate risk (Takashi and Atsushi 1997). In historic areas, it brings together different stakeholders—citizens, experts, and governments—to assess the risks to their cultural heritage. This exercise aims to prepare people and places to respond to disasters by fostering collaboration and prompting discussion on potential risk mitigation measures. It is also a forum for developing strategies to keep communities involved in maintaining and protecting their cultural heritage.

Participants at UR2018 session on cultural heritage play the DIG.
Photo: © Barbara Minguez Garcia.

The methodology is as follows:

1. Using a base map of the heritage area, participants identify key information, such as heritage buildings, water resources for firefighting, open/safe areas, and vulnerable areas for residents/tourists.
2. Participants imagine a disaster scenario, such as a severe earthquake, and identify possible collapsed buildings, blocked streets, and water/power outages, and mark them on the map.
3. Participants discuss emergency response measures, such as potential firefighting methods, and suggest possible routes for emergency teams, firefighting, and access to water.
4. Participants imagine the evacuation options from buildings to safe spaces, for both people and movable heritage. Key questions are these:
   - What is at risk (e.g., specific cultural sites, residents, tourists)?
   - How and how often will hazards affect this area?
   - What are the specific vulnerabilities (e.g., flammability, lack of awareness)?
   - What could happen to the people/cultural sites—i.e., could people/items be rescued, and could sites be repaired or replaced?

for Cultural Affairs (ACA) assessed seismic risk in 2,942 of Japan's 4,695 cultural properties. ACA found that 57 percent needed in-depth professional assessment, and 6 percent were at risk of collapse. Based on the results, ACA crafted new policies and programs to help cultural property owners, and more than 1,000 owners (30 percent) have reported taking action to protect their sites.

ACA emphasizes education and awareness raising for disaster risk activities and has developed several knowledge products: (1) a DRM checklist for cultural property owners; (2) guidelines for ensuring safety of cultural properties (buildings) during earthquakes; and (3) a brochure for cultural property owners, including guidance on why and how to do a seismic risk assessment.

Challenges and Lessons Learned

The increase in disaster risk arising from climate change, risk-insensitive land development, and other factors puts cultural heritage at greater risk of loss.

One way to address this challenge is to bring the DRM and heritage sectors together to undertake risk identification and communication for cultural heritage. This approach helps professionals and stakeholders (1) understand the scope of cultural heritage at risk and (2) communicate likely impacts to inform planning and preparation.

A second way to address the challenge of increasing risk to cultural heritage is to recognize the important role of local communities. Communities can protect cultural heritage, create resilience, and share traditional knowledge (which in many cases provides good DRM solutions). To engage communities, teams working in disaster prevention and heritage conservation can use interactive tools such as the Disaster Imagination Game (DIG), described in box 1.

The Way Forward

Identifying and communicating risks to cultural heritage assets is a crucial step for preserving our past. It allows site managers to protect sites, communities to prepare for likely scenarios, and policy makers to prioritize risk management investments. Some other important steps are these:

1. Include cultural heritage in risk assessments and provide risk information in understandable and usable formats to managers of cultural heritage sites.
2. Emphasize risk communication and collaboration, including exchange of data/information, between DRM and cultural heritage agencies.
3. Foster the development of quantitative and qualitative tools for risk assessment of cultural heritage sites.
4. Encourage the use of games (such as DIG), simulation exercises, and drills to engage local communities and other stakeholders.

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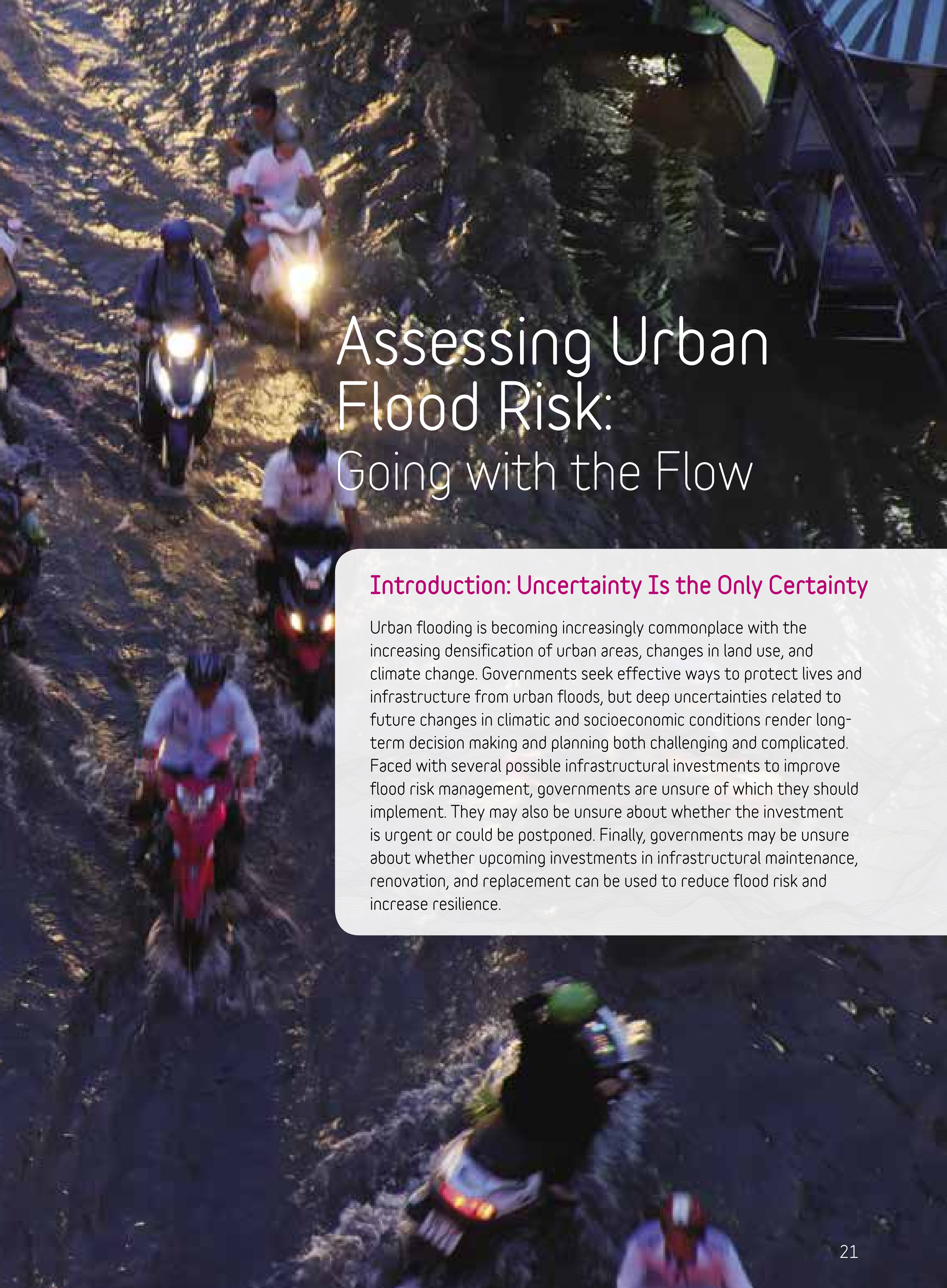
Ho Chi Minh City, Vietnam. Photo: xuanhuongho.



Assessing Urban Flood Risk:

Going with the Flow

Introduction: Uncertainty Is the Only Certainty

Urban flooding is becoming increasingly commonplace with the increasing densification of urban areas, changes in land use, and climate change. Governments seek effective ways to protect lives and infrastructure from urban floods, but deep uncertainties related to future changes in climatic and socioeconomic conditions render long-term decision making and planning both challenging and complicated. Faced with several possible infrastructural investments to improve flood risk management, governments are unsure of which they should implement. They may also be unsure about whether the investment is urgent or could be postponed. Finally, governments may be unsure about whether upcoming investments in infrastructural maintenance, renovation, and replacement can be used to reduce flood risk and increase resilience.

Box 1. Generate Adaptation Pathways for Free!

During the session, the audience had the opportunity to try out the adaptation pathways generator, which involved a hypothetical scenario (the flood-prone city of Fantasia anticipates that flooding will worsen in the future) and live polling (to determine which mitigation measures—e.g., green infrastructure, dredging, and embankments—the city should implement). Developed by Deltares and Carthago Consultancy, the pathways generator allows users to explore and create policy pathways in an interactive way. It can be downloaded free of charge from the Deltares Public Wiki site at https://publicwiki.deltares.nl/display/AP/Pathways+Generator.

Possible adaptation choices offered by the adaptation pathways generator are shown below. Through live polling, session participants selected the measures to be implemented and the sequence in which to implement them.

1 Flood-proof houses and infrastructure

2 Construct green roofs

3 Increase infiltration (pavements, parking lots, etc.)

4 Improve storage (ponds, underground reservoirs, etc.)

5 Construct dikes around critical infrastructure

6 Remove rubbish from and dredge drainage channels

7 Construct new drainage channels

8 Install pumps

Source: Marinus Vis.

As mathematics professor John Allen Paulos once said, "Uncertainty is the only certainty there is." This truth seems to apply to an increasingly erratic climate system, especially so when we are caught off guard by a weather or climate anomaly. Thus the traditional approach to developing urban flood management plans—one based on predictable futures—is quickly losing ground. If the future turns out to be different from what was hypothesized, the plans are likely to fail.

Cities face a number of common difficulties when it comes to planning for long-term urban flood management, especially given the uncertainty brought about by climate change. These include (1) communicating climate change uncertainty to stakeholders and deciding on concrete measures given the inherent ambiguity; (2) prioritizing measures and investments given limited public resources; and (3) determining if future investments in infrastructural maintenance, renovation, and replacement can be used to reduce flood risk and increase resilience.

Urban flood managers are responding to the challenges posed by uncertainty in different ways. In Tokyo, for instance, the government is conducting vulnerability assessments for existing measures to further enhance their resilience. In Jakarta, the need to address urgent flooding problems has prompted the government to implement emergency countermeasures (no-regrets measures), which include the construction of a mega seawall.

As these examples make clear, the large expense and long-lived consequences of urban flood management investments call for flexible and robust plans that can deal with conditions of deep uncertainty. To support the development of such plans, the Dynamic Adaptive Policy Pathways (DAPP) approach was developed by Deltares and the Delft University of Technology (TU Delft).

At the UR2018 session on urban flood risk, experts from Argentina, Indonesia, Japan, the Netherlands, and Vietnam reflected on their experiences managing urban floods, with a focus on how adaptive approaches like DAPP can help resolve some of the challenges they face. The session looked at examples of the use of DAPP, considered some of the challenges involved in developing it further, and offered the audience an opportunity to try out an interactive adaptive pathways tool (see box 1).

Concepts: Adaptive Pathways Approach

The basic aim of adaptive planning is to generate a wide array of pathways through which policy objectives are achieved under changing climate and socioeconomic conditions. Three key elements are central to the adaptation pathways concept:

1. Responses to changes are effective under the widest set of all plausible future scenarios.
2. Responses do not foreclose future options or unnecessarily constrain future choice.
3. Relevant changes are foreseen through targeted monitoring, and scenarios of the future are continuously reassessed.

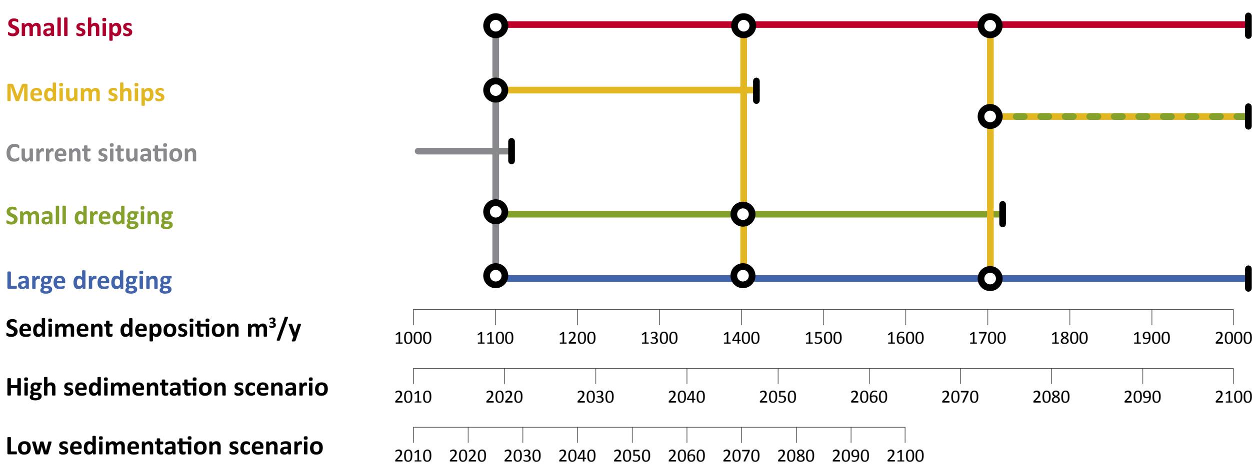
Adaptation pathway mapping is a way of planning a journey toward sustainable urban flood management. It involves exploration of multiple routes and takes into account each route's cost and consequences. This approach helps to analyze different adaptation pathways—that is, different routes into the future.

Each adaptation pathway consists of a series of actions. An adaptation tipping point is reached when the magnitude of external change is such that a chosen action no longer can meet its objectives—for example, when sea levels have risen to exceed the height of protective seawalls. At that point, planners can change route by switching or adding actions so that the ultimate objective can be achieved (see figure 1).

Pathways differ in the actions they entail, the benefits they give rise to, and the investments they require. Some pathways are robust while others are flexible. The choice depends on stakeholders' preferences and the resources available. But all have one thing in common: they result in an urban flood management strategy that is effective at any point in time between the present and the distant future.

This approach allows us to plan in anticipation of change and to avoid

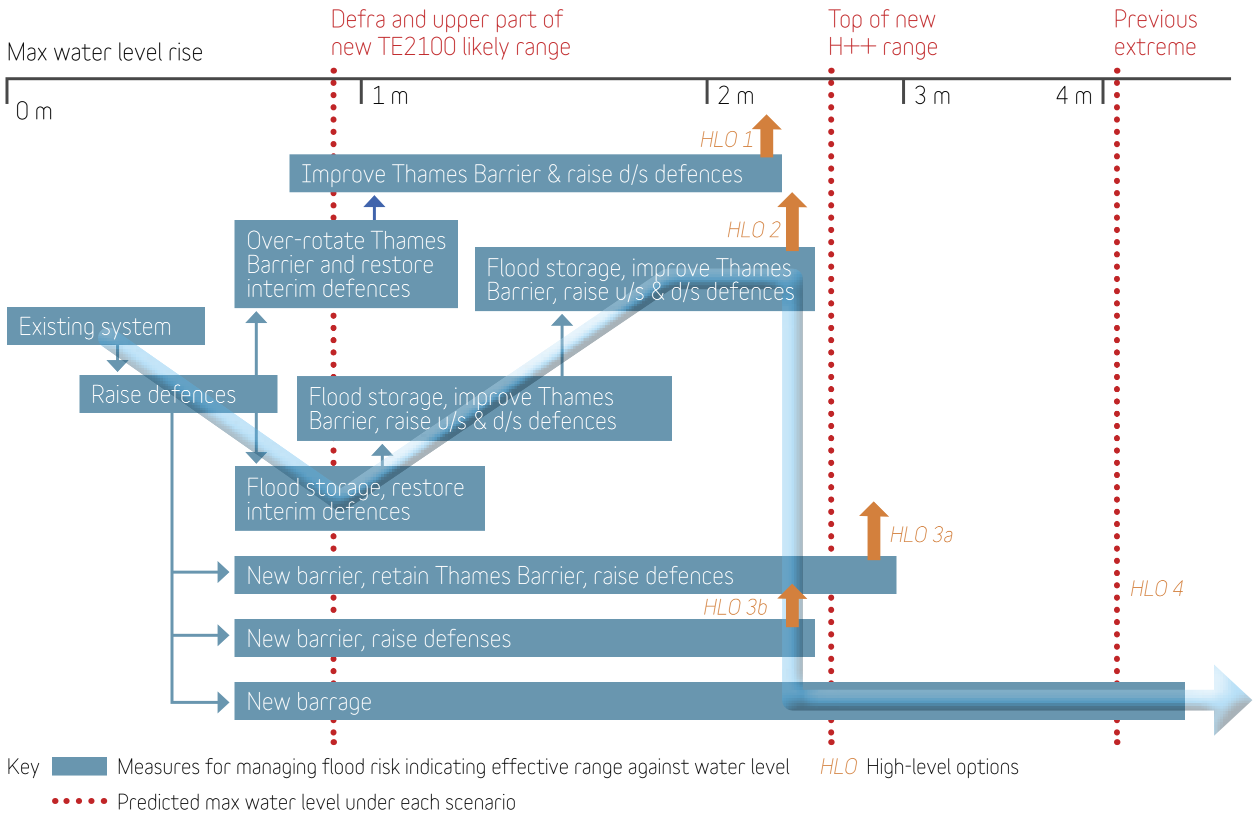
Figure 1. An adaptation pathways map



Map generated with Dynamic Pathways Generator, 2015, Deltares, Carthago Consultants.

Source: https://publicwiki.deltares.nl/display/AP/Pathways+Generator. @ Deltares and Carthago Consultancy. Licensed under Creative Commons Attribution-NoDerivatives 4.0 International License.

Figure 2: Adaptation pathway map for the Thames Estuary.



Source: UK Met Office 2009.

regret over doing too little too late, or too much too soon.

Case Study

Managing Flood Risk in the Thames Estuary

In the United Kingdom, the use of adaptation pathways was pioneered by the Thames Estuary 2100 (TE2100) project, which produced a plan for managing tidal flood risk in the Thames estuary and London. The TE2100 plan has a set of options based on adaptation pathways that can cope with a range of maximum water levels, from those experienced at the start of the century to a worst-case scenario by 2100. The preferred pathway includes staged long-term modification of the Thames Barrier and the management of fluvial and pluvial flooding through local measures, including making space for water, building local flood defenses, developing resilience measures, and engaging in flood forecasting and emergency planning. TE2100 sets a long-term strategic vision of how London can adapt and establishes the potential need for transformational change in the long term (see figure 2).

Challenges for Further Developing the Adaptation Pathways Approach

Further developing the DAPP approach entails several challenges:

- *Determining tipping points.* The adaptive approach works best for gradual-trend-dominated developments like sea-level rise, which force clear-cut decisions on (for instance) the upgrade or replacement of flood surge barriers. But in the absence of precise policy goals or in situations of large natural variability, determining tipping points can be challenging. If the exact tipping point cannot be pinned down, it is hard to decide when to implement the next set of measures.

- *Maximizing broad commitment in situations of low predictability.* Adaptation pathways make explicit what measures can be taken in the short term and sketch possible future measures. Decisions about these future measures can be taken in due time. In practice, final decisions about the actual implementation of these future measures are often not taken before expected physical conditions (climatic, socioeconomic) are actually met or can be predicted with relative certainty. For this reason, it can sometimes be challenging to garner broad support for these measures.

- *Unraveling the relations between parallel strategies implemented simultaneously.* In theory, adaptation pathways consist of several parallel trajectories and include the possibility of switching from one trajectory to another when conditions are met. A strategy composed of several parallel trajectories contributes to the system's resilience, because it has more fallback options in case some of the trajectories do not perform as expected. But different trajectories often address completely different actors and have uncertain chances of successful implementation. This interrelatedness is complex, and its implications need to be better understood.
- *Switching from incremental to transformational strategies.* Real-life decision making is often influenced by institutional and political considerations. The DAPP approach does not automatically address the political aspects of decision making, meaning that conservative powers could block or slow down necessary transformations. The governance challenges have remained implicit in the adaptation pathway approach, but they are considerable.

Conclusions

Societies and decision makers have always had to make choices based on imperfect knowledge and deep uncertainties. With climate change, the scale of change is highly uncertain, and it is possible to imagine reaching a point at which decisions can no longer be informed by historical experience. Adaptive planning aims to ensure strategies that cost-effectively reduce risk while being flexible enough to adapt to an uncertain future. In summary, the adaptive pathways approach offers these key benefits:

- Informs and mobilizes decision makers
- Encourages approval and buy-in from stakeholders
- Creates political support for keeping long-term options open
- Increases awareness about uncertainties
- Helps to incorporate long-term objectives in short-term decisions
- Offers visualization of multiple alternatives

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Side Event

City Coastal Resilience: How Would YOU Protect Africa's Coastal Cities from Climate Change?

African cities are growing rapidly. By 2030, cities in coastal flood plains and low-elevation coastal zones are expected to double in size. As populations inch closer to the coast and densify in low-lying areas, they become more vulnerable to disaster and the detrimental effects of climate change. Many African coastal cities are already feeling the impacts of flash floods, sea-level rise, erosion, land subsidence, and storm surge. Adaptive measures can be taken to reduce or avoid disaster—but how do cities adapt when risk information is inaccessible, destructive behaviors are unyielding, and financing is limited?

UR2018 participants sought to answer these questions in an intensely interactive disaster risk management planning exercise at the City Coastal Resilience in Africa (CityCORE) event. Given a budget of 250 "tokens," four teams gathered to build innovative, financially sustainable, and resilient adaptation plans for African coastal cities for the year 2050.

- **Mogadishu, Somalia:** National conflict and instability have left Mogadishu without resources for environmental and urban management. For this reason, the Mogadishu team chose to invest in establishing an environmental protection agency to spearhead adaptation efforts. Recognizing the vulnerable position of internally displaced people in Mogadishu, the team also devoted funds to collecting data on migration, education, and economic opportunities away from exposed areas of the coast and inland. Data collection would be community based to increase local capacities and to recognize the role that clan leadership may play in adaptation.
- **Saint-Louis, Senegal:** In Saint-Louis, floods and erosion are displacing fisher households, a situation that will worsen with climate change. In an innovative bid, the Saint-Louis team proposed to relocate fishers to new floating houses among mangroves in the Senegal River estuary. Additional small investments in flood risk mapping would yield informative results for urban planning, while a seawall and groins along the coast would offer protection from the Atlantic's rising waves.
- **Nouakchott, Mauritania:** Like many urban areas in Africa, Nouakchott has poor drainage and a sewer system with inadequate capacity. Meanwhile, unstable soils from erosion and subsidence increase the risk of building instability and

Fish market in a coastal city in Senegal. Photo: Fabian Plock.

collapse. The Nouakchott team identified priority area drainage construction as key to alleviating flooding for the growing population. The team coupled this infrastructure measure with information-gathering measures to better understand Nouakchott's risk situation, including a geospatial data portal for risk data sets, new sediment analysis, and a social impact assessment. These measures would inform new regulations in land use and zoning to mitigate exposure.

- **Beira, Mozambique:** Cities along the coast of Mozambique are seeing streets washed out and seaside infrastructure damaged by tropical cyclones. The Beira team's plan centered on policy change and civic engagement. Policy measures incentivize the installation of permeable surfaces and underground storage tanks, while a new smartphone app offers two-way communication on localized flooding and health risk. These innovations are linked to parametric insurance, with payments triggered by extreme rainfall forecasts.

The disaster risk management planning exercise was preceded by talks from experts in climate change adaptation and remote sensing. John Furlow (International Research Institute for Climate and Society) gave a keynote address on the potential and challenges of national adaptation plans for addressing climate risks. Fabio Cian (Ca' Foscari University of Venice) illustrated how advances in Earth observation can inform urban planning and risk reduction efforts through land subsidence monitoring. He illustrated the use of Synthetic Aperture Radar data in an interferometric analysis to assess land deformation in 18 coastal African cities; about 1,000 images from the European Space Agency's Sentinel-1 satellite (from late 2014 to early 2018) were employed to detect subsidence hot spots in need of a specific adaptation plan.

Finally, Lorenzo Carrera and Grace Doherty (World Bank) discussed CityCORE's city-level risk and data studies in 16 cities across the African coast, whose findings can be used to prioritize and target adaptation measures at the municipal scale.

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Side Event

Understanding Disaster Risk in Situations of Fragility, Conflict, and Violence

The Background

The international community is facing an era of unprecedentedly complex crises. An increasing number of countries are affected by both disasters triggered by natural hazards and protracted crises associated with fragility, conflict, and violence (FCV). The effects of hazard events and FCV are often mutually reinforcing: Disasters can exacerbate the risk of conflict—for example through poorly managed response that deepens grievances among different groups. At the same time, conditions of conflict can increase the likelihood of disasters, such as when conflict displaces people into hazard-prone areas.

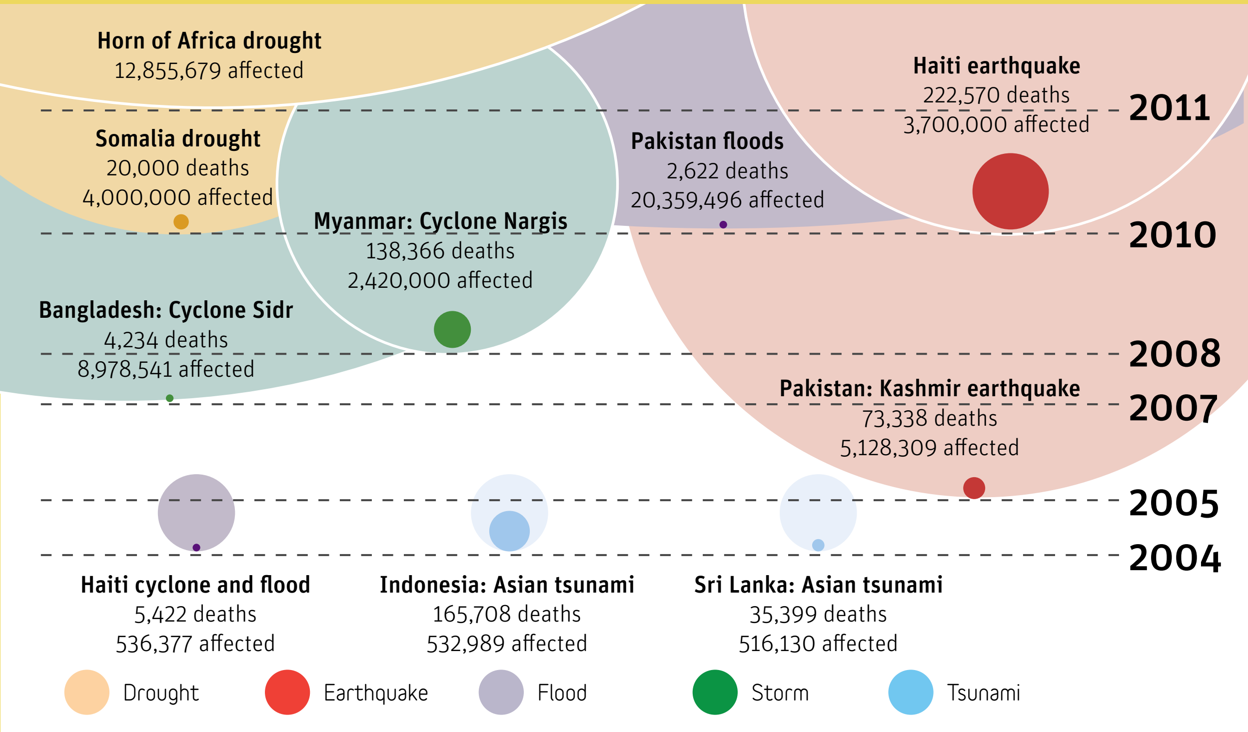
Disasters are not conflict-neutral. Fundamental components of disaster risk—such as exposure, vulnerability, and (lack of) capacity—are governed by the socioeconomic and political conditions in which people live. FCV settings thus influence how, where, and when disasters happen, and they therefore need to be part of the conversation about how disaster risk can be reduced.

Against this background, UR2018 brought together disaster risk management (DRM) experts from various organizations—including the World Bank, Global Facility for Disaster Reduction and Recovery (GFDRR), United Nations Development Programme (UNDP), United Nations Office for Disaster Risk Reduction (UNISDR), German Agency for International Cooperation (GIZ), Overseas Development Institute (ODI), and International Federation of Red Cross and Red Crescent Societies (IFRC)—to start a conversation on how to improve risk reduction in FCV contexts.

The Challenge

Impacts of natural hazards hit those living in fragile and conflict-affected contexts hardest (see figure 1). Between 2004 and 2014, 58 percent of global deaths from disasters occurred in the 30 most fragile states (Peters 2017). Yet notions of fragility, violence, and conflict are largely absent from disaster risk reduction (DRR) policies, programming, and financing architecture. The Sendai Framework does not

Figure 1. Impact of selected disasters in fragile and conflict-affected states. The events shown are among the top-50 most deadly natural hazard events in the period 2004 to 2014.



Source: Peters and Budimir 2016 using data from EM-DAT. ©Overseas Development Institute.

consider FCV conditions as an underlying driver of vulnerability. In addition, multilateral and bilateral investments in DRM in fragile countries fall far short of what is needed. Between 2005 and 2010, for every US$100 spent on humanitarian response in fragile states, only US$1.30 was spent on DRM (Peters and Budimir 2016).

What Is Needed?

On the policy level, there is a need to influence the delivery of national, regional, and international commitments to achieve the goals of the Sendai Framework. For this we need to compile robust evidence, convincing data, and good practice examples showing that DRM works and makes a difference in fragile and conflict-affected countries.

With respect to programming, there is a need to adjust DRM approaches to the special challenges in FCV settings and integrate DRM into strategies for stabilization and peacebuilding. Investments must be monitored to measure their effect on disaster risk as well as their impacts (intended or unintended) on conflict dynamics.

Regarding financing, there is a need to increase fragile and conflict-affected countries' access to DRM finance; this will strengthen their implementation capacities and their ability to crowd in private sector investments where appropriate.

Syrian Kurdish refugees sit around a fire on their way from Turkey to the heart of Europe. Photo: Joel Carillet

Looking Forward

Session participants have decided to form the core of an informal group of champions of the theme. Based on a mapping of actors with relevant experience (DRM in FCV settings, conflict prevention and peacebuilding), the group will incrementally reach out to additional partners to form an influential community of practice.

The participants also agreed to share knowledge, data, tools, and good practices and organize focused technical meetings to analyze what types of DRR actions work in FCV settings. The minimum objective should be to ensure that DRM interventions do no harm by avoiding negative impacts on the underlying conflict dynamics. In situations where DRM opens paths for dialogues about conflict and peace, DRM interventions can actively seek to address the underlying drivers of conflict and contribute to peacebuilding efforts. The collated information will be made accessible through the creation of a knowledge hub that supports the DRM community in operating in fragile and conflict-affected contexts.

The group will collaborate to influence international policy discussions by organizing joint events at major conferences, such as the upcoming Regional and Global Platforms for Disaster Risk Reduction, to ensure the topic receives the required political and financial support.

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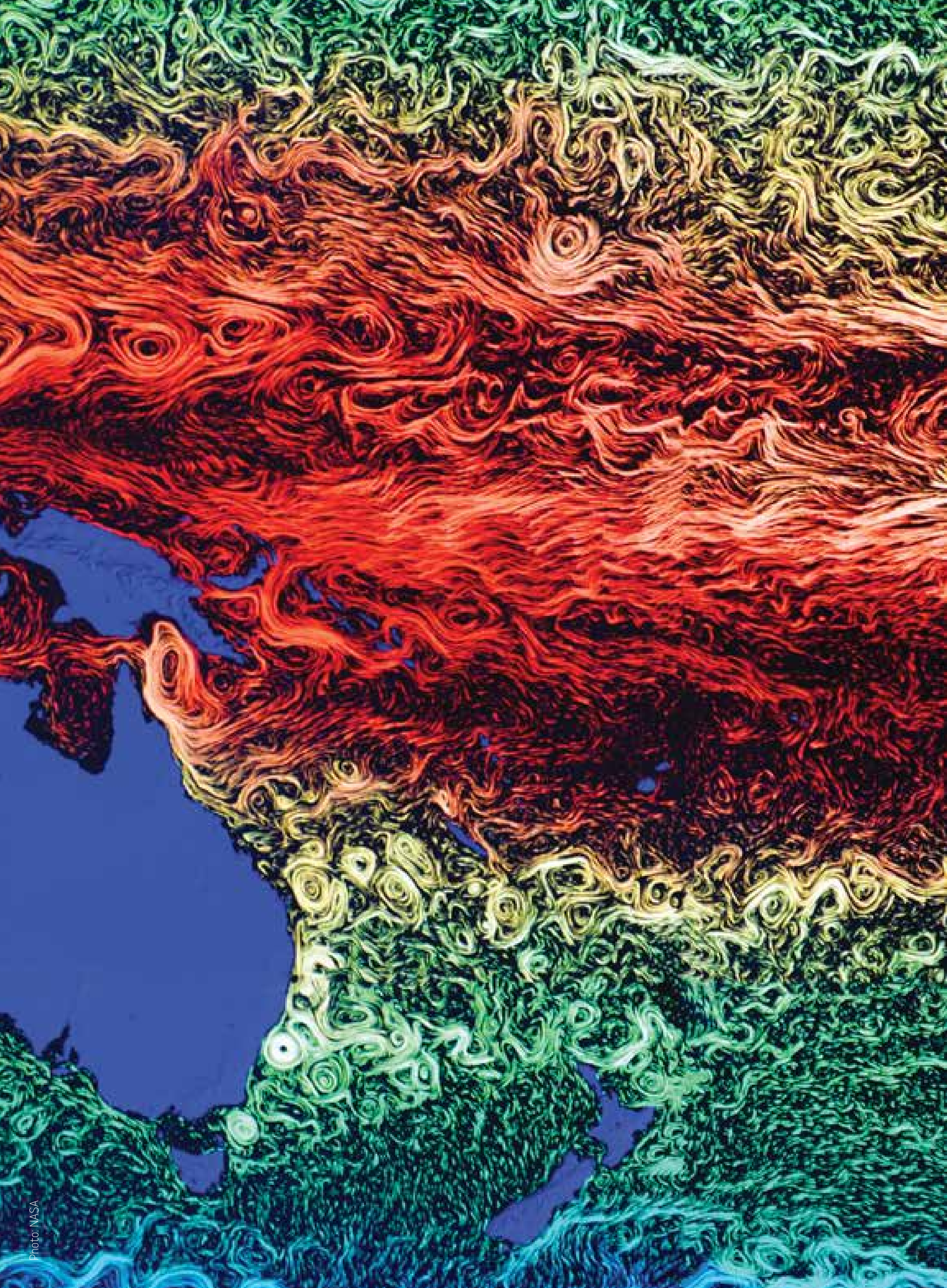
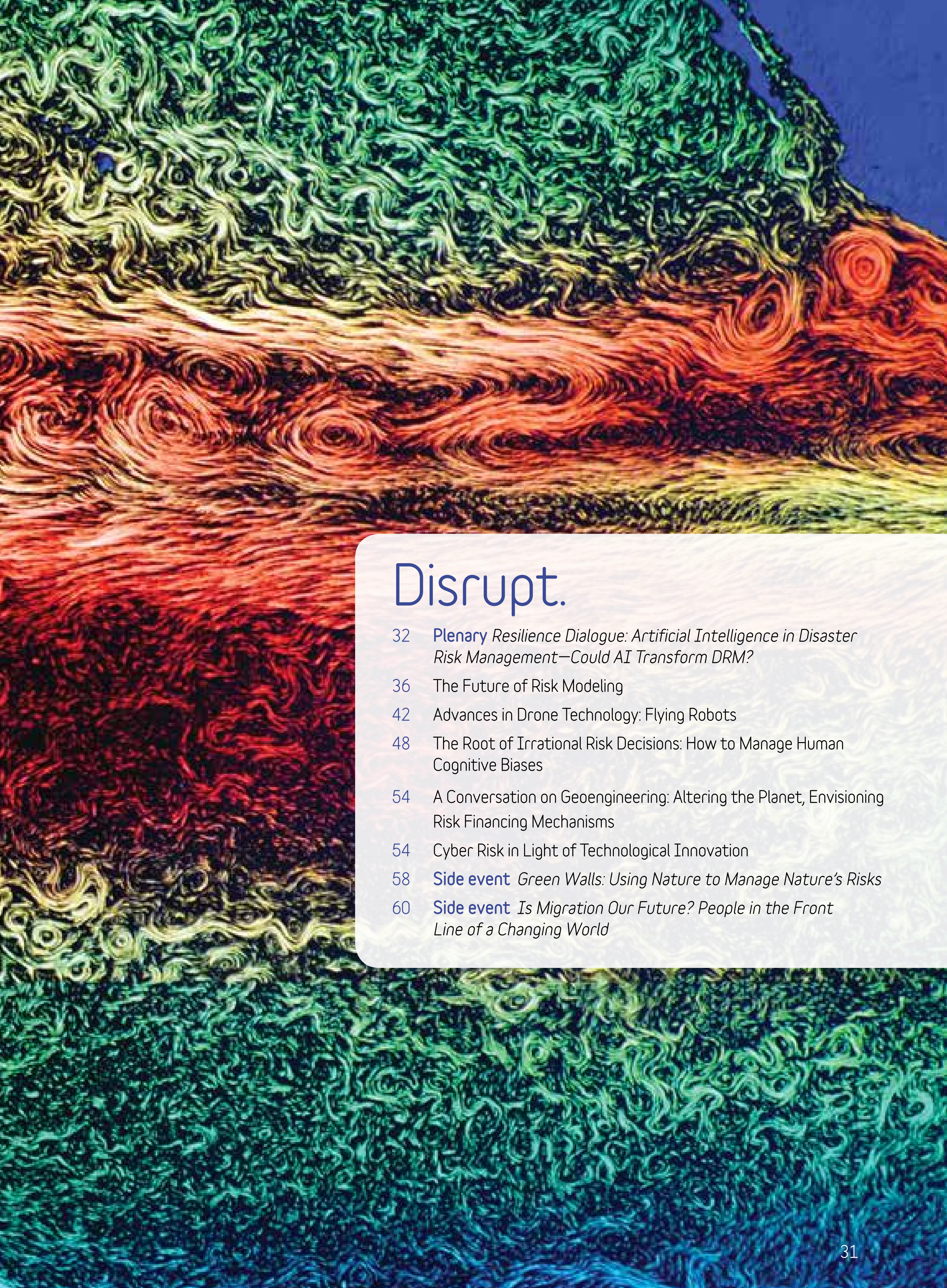


Photo: NASA



Disrupt.

32 **Plenary** *Resilience Dialogue: Artificial Intelligence in Disaster Risk Management—Could AI Transform DRM?*

36 The Future of Risk Modeling

42 Advances in Drone Technology: Flying Robots

48 The Root of Irrational Risk Decisions: How to Manage Human Cognitive Biases

54 A Conversation on Geoengineering: Altering the Planet, Envisioning Risk Financing Mechanisms

54 Cyber Risk in Light of Technological Innovation

58 **Side event** *Green Walls: Using Nature to Manage Nature's Risks*

60 **Side event** *Is Migration Our Future? People in the Front Line of a Changing World*


Photo: MF3d.

Resilience Dialogue: Artificial Intelligence in Disaster Risk Management—Could AI Transform DRM?

The technological revolution we are all now part of is fundamentally different from anything humanity has experienced in the past. Its implications for the future of sustainable development are enormous. Technology-driven trends are disrupting the way institutions like the World Bank carry out their work by opening promising new avenues for sustainable, inclusive, and smart development.

Disruption and "exponential technologies" are helping us reach development goals faster and more efficiently. Technologies such as artificial intelligence (AI), robotics, and blockchain are changing how we live, work, and organize ourselves and our institutions. At the World Bank Group, we are incorporating disruptive technologies into our sustainable development work. For example: in Zanzibar, the World Bank is using drone technologies as part of a mapping initiative to update land records for urban planning and flood control. In India, Internet of Things (IOT) solutions have been used to track and monitor indoor pollution and its impact on health. On a more global scale, blockchain and distributed ledger technology are being tried out as a way of capturing and tracking carbon emissions data.

Artificial intelligence is also transforming the field of disaster risk management (DRM). Intelligent use of satellite imagery can help detect tsunamis by identifying unusual sea behaviors in real time, or landslides by recognizing changes in slopes. Similarly, AI applied to satellite imagery can help detect millimeter-scale deformations, provide a synoptic view of terrain and infrastructure stability, and reduce the damage caused by collapsing buildings or subsiding roads and bridges. With the practical implementation of AI in satellites, a significant amount of time and money can be saved.

Recognizing the great potential of AI for disaster risk prevention and preparedness, UR2018 included a plenary session on AI that explored both the opportunities it offers and some of its risks.

Background and Concepts

In 1951 Alan Turing posited that "if a machine can think, it might think more intelligently than we do." In general terms, AI refers to a broad field of science encompassing not only computer science but also psychology, philosophy, linguistics, and other areas. It is concerned with getting computers to do tasks that would normally require human intelligence. By providing new information and improving decision making through data-driven strategies, AI could potentially help solve some complex global challenges. Machine learning techniques are already tackling problems at a scale beyond human capability—for example, revealing valuable patterns in large data sets.

On the other hand, leading entrepreneurs and scientists are concerned about how to engineer intelligent systems, which implicitly take on social obligations and responsibilities. Risks could emerge from mismanagement, design vulnerabilities, accidents, and/or unforeseen consequences. While artificial general intelligence (AGI)—that is, "strong," human-level intelligence—is still a long way off, "weak" artificial specialized intelligence (ASI) geared toward solving specific problems is already an integral part of our daily lives.

Machine learning is a critical subset of AI that focuses on developing algorithms that parse data, learn from that data, and then apply what they've learned to make informed decisions. Machine learning does require some guidance when training algorithms: if an algorithm returns an inaccurate prediction, an engineer will need to make appropriate adjustments. Deep learning is a subset of machine learning that develops models capable of learning without human guidance. It works by leveraging a layered structure of algorithms called an artificial neural network, which mimics the behavior of biological neural networks. Deep learning is feasible today because of the vast proliferation of structured and unstructured data, the affordability of cloud storage, and the comparatively low cost of computing.

This is a new field but one that holds great promise in "humanizing" the machine—i.e., teaching machines positive and ethical behaviors through good (large and well-documented) data sets.

Given that 2.5 quintillion bytes of data are generated every day,[1] AI can be used to discover structure in raw data that unlocks a range of development solutions, from the prediction of disasters to the identification of genetic mutations that cause disease.

In the World Bank Group, AI and machine learning algorithms have been applied to household surveys in Tanzania, Ghana, Niger, and Mexico to produce new and customized poverty data; and image recognition technology is being used in Guatemala to detect buildings' structural vulnerabilities as part of disaster risk prevention.

Case Studies

The session began with a look at the application of ethics to artificial intelligence and machine learning. This is a new field but one that holds great promise in "humanizing" the machine—i.e., teaching machines positive and ethical behaviors through good (large and well-documented) data sets. (In providing the examples used to train machine intelligence, data sets may actually be more important for AI than algorithms).

A huge collaborative effort is now under way to construct, collect, and annotate data sets that can be used to develop socially aware thinking machines. The necessary data sets will represent diverse cultures and belief systems, and will be flexible enough to allow for growth in scope and nuance over time. The goal is for the resulting socially aware AI to promote better decision making and to create trust (defined as consistency over time) through verifiable behavioral rule sets—and in this way to make the world a safer and more just place.

To ensure that diverse ethical notions are represented, the project seeks to ensure open access to—and opportunities to contribute to—the data. This is not possible under the current system, which is dominated by a limited number of AI researchers and engineers. Building a widely representative data set that can express ethical behaviors computationally is a daring undertaking, but one that could potentially provide the world with an essential enabling technology.

This broad look at the application of ethics to AI was followed by a discussion of how AI can be effectively utilized in the field of DRM. One approach currently being used combines hazard modeling with machine learning and artificial intelligence so that communities are better prepared before and after a disaster strikes.

Traditional disaster models rely on either high-resolution asset-level data or low-resolution unidimensional data. The former require extensive pre-disaster data collection and make it computationally expensive to estimate damage within minutes of a disaster, while the latter provide only aggregated impact estimates that are too coarse to be actionable.

Under the new approach, asset-level data are gathered from various public and proprietary sources (e.g., satellites, censuses) in a scalable process, along with impact data from previous disasters. These are then inserted in data-driven machine learning models that require no user inputs and can produce impact outputs at high spatial resolutions within minutes. Real-time disaster data (such as ground shaking, water levels, temperature, and wind patterns from satellites and weather data) are also utilized to generate highly accurate localized impacts that are updated continually as more information becomes available. Real-time input streams are used to update the predictions not only at the location of the input but also in its vicinity, so that the impact predictions become more accurate over time.

This interdisciplinary approach takes into account multiple hazard models and dynamic data. It trains models on true observations of damage, and by seeking solutions that allow for unprecedented situational awareness, informs better decisions.

[1] IBM, "10 Key Marketing Trends for 2017 and Ideas for Exceeding Customer Expectations," https://www-01.ibm.com/common/ssi/cgi-bin/ssialias?htmlfid=WRL12345USEN.

Conclusions

AI holds the potential to deliver on important promises, but there are also inherent risks in the use of artificial intelligence in programs and policies, including algorithmic bias and privacy concerns. The World Development Report on the economic benefits of digital technology (World Bank 2016) argued that these technologies have spread rapidly in much of the world, boosting growth, opportunities, and service delivery; yet their aggregate impact has fallen short of what is possible and is unevenly distributed. For example, while access to Internet globally has grown exponentially, from 1 billion in 2005 to 3.2 billion in 2015, 71 percent of households in the bottom 40 percent of the population continue to lack access to the Internet.

Supporters of technological development argue that automation through artificial intelligence and robotics can potentially create more jobs overall, but many in the workforce will be unprepared to fill them if training in relevant skills is not also provided. Moreover, the widespread sharing of data raises issues of privacy and cybersecurity and potentially erodes individuals' trust in governments and institutions.

For digital technologies to benefit everyone everywhere, we need to close the remaining digital divide by ensuring universal Internet access, strengthening competitiveness regulations, adapting workers' skills to new demands, and ensuring that institutions are accountable.

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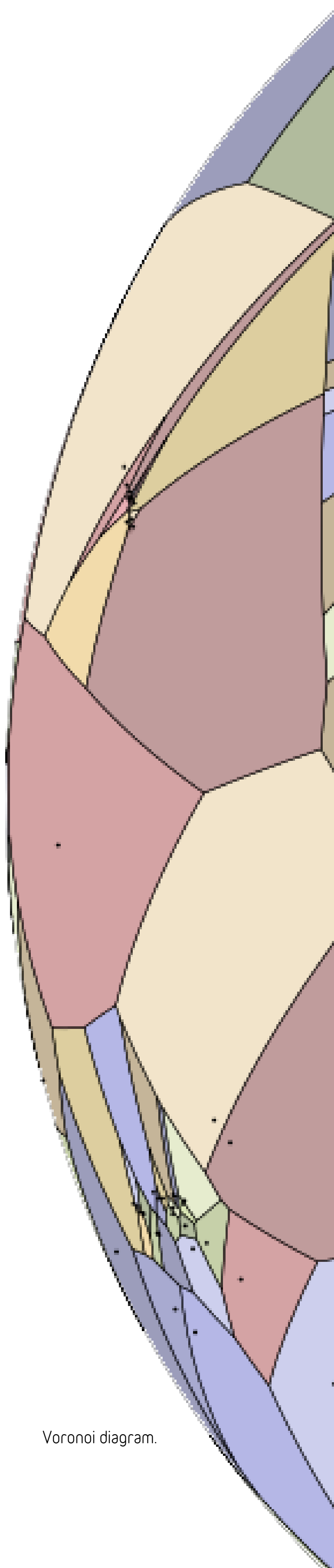
Recently, the entire United States was mapped by machine-learning algorithms that processed nearly 200 million aerial images in just over 10 minutes.

The Future of Risk Modeling

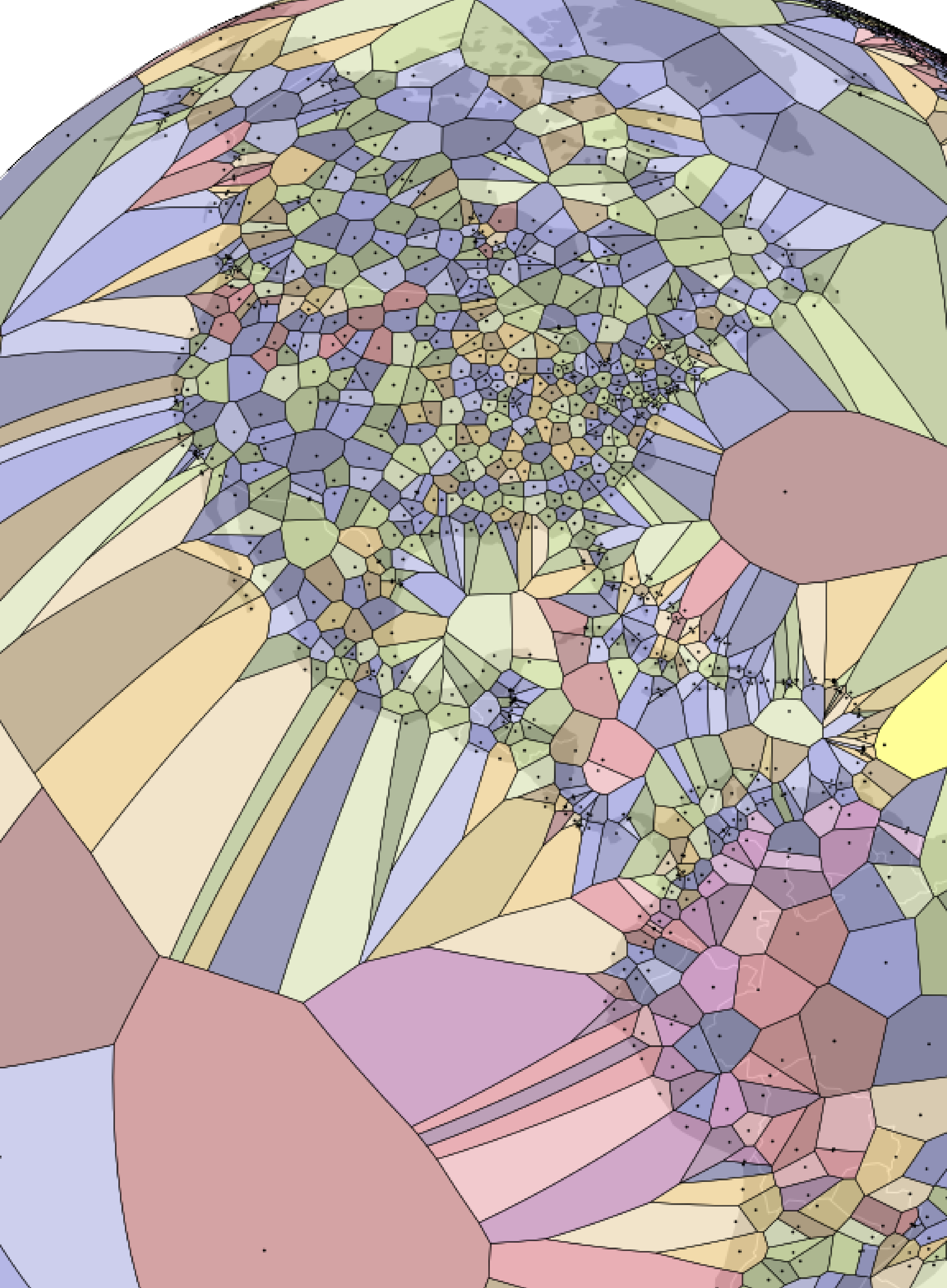
Introduction

Advances in computational capabilities and communications seem likely to increase our ability to model and assess risk. But this increase does not automatically increase resilience or motivate actions to reduce risk. How can we communicate risk results in a way that promotes effective action, teaches lessons from past experience, prompts changes in behavior, and helps us reduce risk and increase resilience?

This UR2018 session sought to review our past and current understanding of risk, explore how our ability to model risk might evolve in the near future, and learn some of the ways that risk information is used for decisions and actions. The session started with a review of the Aztec's understanding of risk, progressed to presentations examining advances in modeling risk, and ended with examples of decisions guided by risk analyses.



Voronoi diagram.



Background and Concepts

Risk models

Risk assessments use data on exposure, hazard(s), and vulnerability to estimate damage and/or loss to an exposure of interest. The exposure represents the population, building, infrastructure, or other asset(s) of interest. The modeled hazard can be one or more perils—for example, flood or earthquake—and sometimes secondary hazards such as liquefaction, landslides, and fires as a result of earthquakes. Man-made hazards such as cyberattacks and terrorism can also be modeled. Vulnerability is quantified using fragility or vulnerability functions that characterize the likelihood that an asset will suffer damage or loss when exposed to the hazard.

The models can be used in a deterministic manner to explore the impact from a single event, for example a simulation of a historical event. With this approach, there is only a single realization of an event, or multiple realizations meant to characterize the uncertainty in the hazard's intensity. Alternatively, a risk model can be used in a probabilistic manner to determine the risk of damage and/or loss from a peril. The catalog of hazard events used to calculate a probabilistic estimate of loss can include tens to hundreds of thousands of events whose characteristics are statistically consistent with the historical record. The catalog should also capture the full range of possible events that could be experienced over (tens of) thousands of years.

Risk model results

Probabilistic risk model results can be expressed using several different metrics. The most common is the average annual loss, which is calculated by adding the loss generated by each event and dividing the total by the number of years represented by the event catalog. Another common metric is the loss that is expected to be equaled or exceeded in a given time span for a given probability—for example, the loss that has a 0.01 probability, or 1 percent chance, of being exceeded each year. The inverse of the probability is used to define the return period loss. Thus, the 100-year loss is the same as the loss that is expected to be exceeded with a 0.01 probability.

Figure 1. A word cloud depicting the self-identified areas of expertise of attendees. Interest in the session spanned multiple disciplines and suggests that effective risk modeling requires multidisciplinary expertise.

Figure 2. A word cloud depicting the self-identified nationalities of attendees. Interest in the session went far beyond a few localities or nations.

Improving future risk models

A "brute force" approach to improving a risk model is to increase model resolution, by (1) increasing the grid resolution used for modeling the hazard, (2) using more detailed site-specific exposure data, or (3) increasing the quality of the fragility and vulnerability functions. However, whatever improvements are considered, the scales used to characterize the hazard, exposure, and vulnerability must be consistent. For example, very high-resolution hazard data are of no value if the exposure data are at an administrative level. Similarly, detailed site-specific exposure information is useful only if fragility or vulnerability functions account for the structural features included in the exposure data.

Beyond data, there are costs related to increasing the model resolution. Computational expense grows as the model resolution increases, and collecting or generating exposure data can also prove expensive and require trade-offs. For example, it may be impractical to develop or purchase a complete database of site-specific building exposure on a national level, and the cost of a high-resolution digital elevation model may preclude the use of a higher-resolution flood model.

Another approach to improving a risk model is to improve the simulation of the peril of interest. For example, instead of just accounting for ground shaking, an earthquake model could include the impact of secondary hazards such as liquefaction, fire, and damage caused by sprinklers set off by an earthquake. It could also account for the earthquake's duration, the direction of wave propagation through the ground, and local soil conditions that can amplify ground motion. Tropical cyclone models could account not just for maximum three-second wind gusts but for coastal and inland flooding, precipitation, and airborne projectiles.

Communicating risk results

Effectively communicating risk is crucial for reducing risk and increasing resilience. But this step can be challenging, for several reasons. First is the need to target multiple audiences—i.e., both decision makers and the public. Second is the difficulty of presenting information on probabilities—for example, on average annual loss or return period loss—to those without much knowledge of or training in this area. Finally, audiences facing routine immediate concerns may not attend to information about a low-probability event, even though its impact could be devastating.

Acting on risk knowledge

Effective communication is necessary for prompting action—but it is not sufficient by itself. The risk assessment must be designed with the needs of the intended user in mind; the results from a "perfect" risk model will not be used if they are not relevant for the user. Perhaps more important, the user must trust the provider and the results; where trust is lacking, even the most relevant results may not be used. One way to build trust is for the user to be involved with commissioning the risk assessment and collecting the data.

Case Studies

Taken together, the case studies presented at this UR session suggest that data and models used to generate risk information have continued to improve, and that developing and improving communication and decision support tools offers the greatest return for efforts to increase resilience and disaster awareness.

Historical view of risk: The Aztecs

The Aztecs were a relatively young civilization when the Spaniards arrived. They had developed a sophisticated system of engineering that included flood control and sanitation, had a base 20 mathematical system, and cadastral and tax records. They also were fans of games of chance. Interestingly, their mathematical knowledge, awareness of probability, and efforts on flood control coexisted with irrational behavior, such as human sacrifice.

The current environment of risk modeling

Quantitative catastrophe risk modeling started in the 1960s, but the first commercially licensed catastrophe risk models were not developed until the late 1980s. These early commercial risk models focused on regions and perils where there was a large insurance market, and they required mainframe computers. Today, models can be run on desktop computers or cloud computing services. Moreover, they now cover regions with small insurance markets and include perils (such as cyber risk and terrorism) that extend beyond natural hazards.

Risk modeling for the developing world

The developing world has an insurance gap relative to the developed world for several reasons, including limited access to insurance products and lack of risk knowledge (due in part to the difficulty of accessing hazard, exposure, and vulnerability data for use in local or regional risk models). Improved computational resources will soon allow the production of credible risk results using high-resolution data and sophisticated global models.

Near-term improvements of risk data and models

The integration of remote sensing observations, crowdsourced mapping, and machine learning will lead to significant improvements in exposure and hazard data. In addition, improved computational resources and higher-resolution data will significantly improve risk models' reliability and accuracy.

Where will disaster risk technology take us?

Currently, most risk-related information is used by the insurance and engineering sectors. However, continued improvements in risk information and results will give rise to new decision-support tools and empower communities by providing better access to and understanding of risk information.

Decision support for resilience

Improved risk information and enhanced access to risk models promote more informed decisions. For example, risk models can be used for cost-benefit studies that guide decisions on disaster risk management.

Communicating risk

Acting to reduce risk and increase resilience requires community support, which in turn requires communicating risk results in a way that citizens can understand. Overcoming barriers that hinder sharing of information and building community trust in risk results are both key steps in risk reduction.

Challenges

Better risk modeling in the future depends on overcoming technical, practical, and social challenges among a wide range of disciplines and across many parts of the world (as shown in the word clouds—figures 1 and 2—depicting the expertise and nationality of the session audience).

Technical challenges include handling large amounts of data, developing standards to facilitate data exchange and model interoperability, and promoting high-bandwidth Internet access across the globe. Practical challenges include expanding the availability of open data and open source tools to minimize the cost of generating and using risk-related data.

Several social challenges remain to be overcome. First are barriers that limit access to data. Data are powerful, and maintaining control of data can be a way of maintaining power. Second are impediments to user trust; even accurate and accessible data won't be used if the provider isn't trusted. Finally, there are difficulties in communicating results in an understandable and actionable way.

Recommendations and Conclusions

We already know how to overcome some of the technical and practical challenges involved in better risk modeling: more and higher-resolution data, more computational resources to run higher-resolution models, and the adoption of data and model standards. But certain practical and social challenges may be harder to overcome. To realize the future of risk modeling, the following approaches may prove useful:

- Create standards for hazard, exposure, vulnerability, and risk results data in order to promote the development of tools for understanding and communicating risk.
- Support the development of open data and open source models and tools.
- Support the expansion of high-speed Internet throughout the developing world.
- Research and develop effective tools for communicating risk.
- Develop standard operating procedures for promoting relationships of trust between providers and users of risk information.

Our rapidly increasing technical and computational abilities ensure better risk modeling over time. However, risk modeling's human component—communicating information and making decisions aimed at reducing risk and increasing resilience—remains challenging. Acknowledging this difficulty should be seen as an essential step toward realizing the future of risk modeling.

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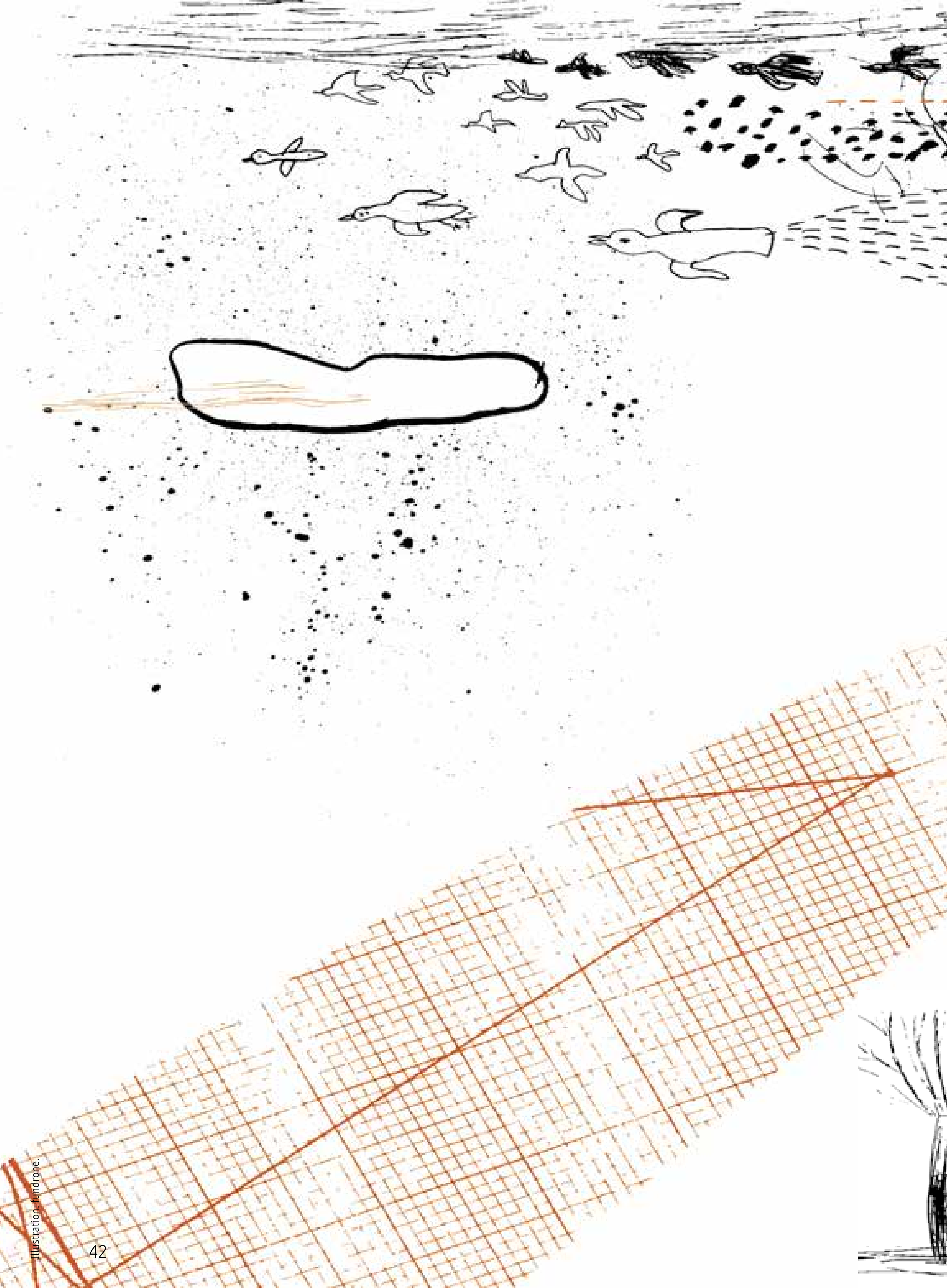

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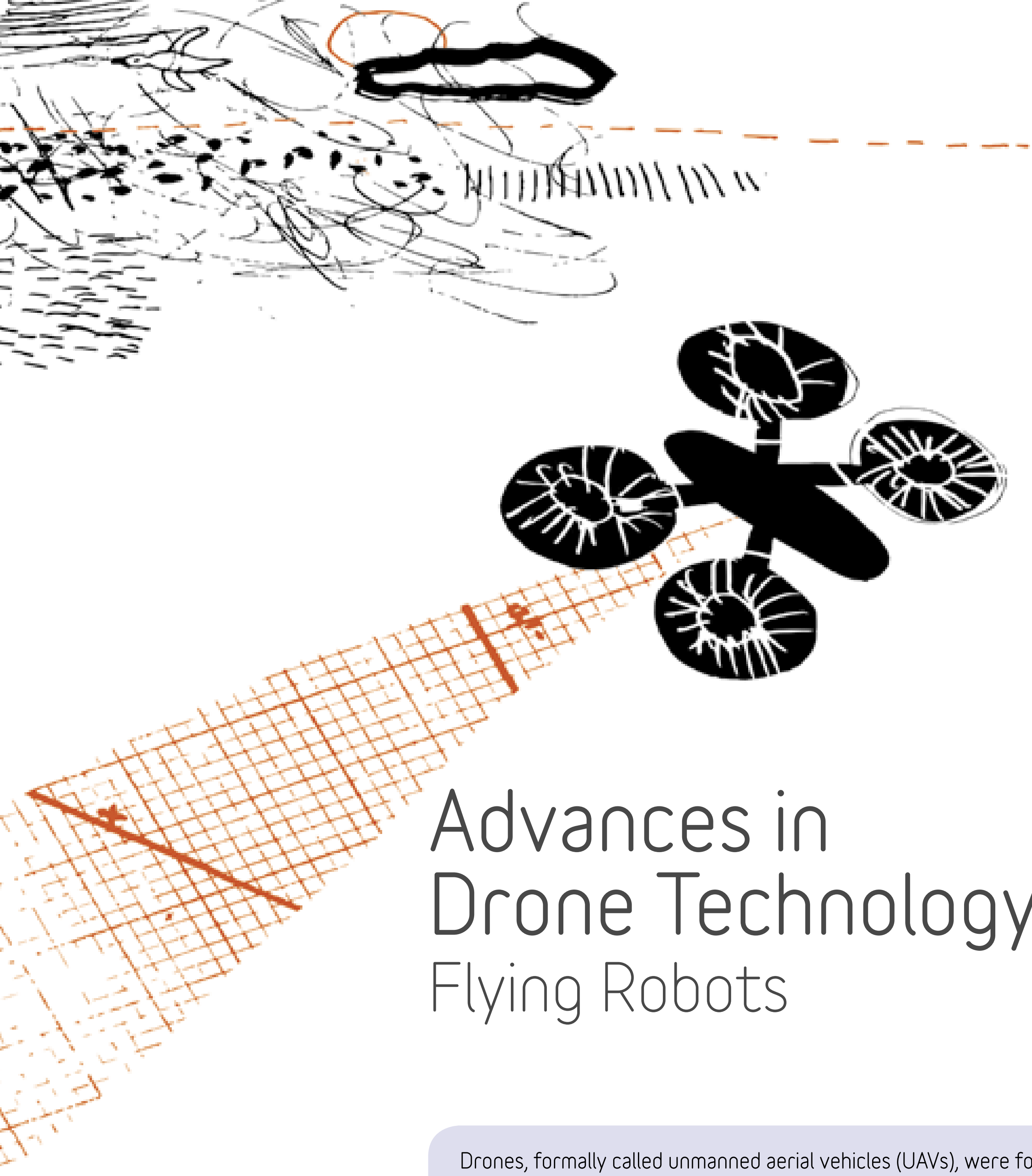
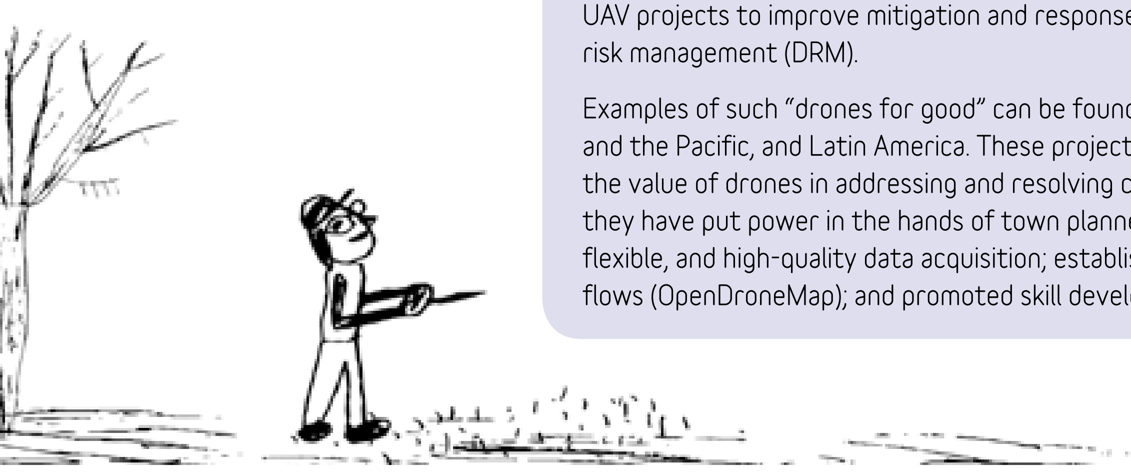
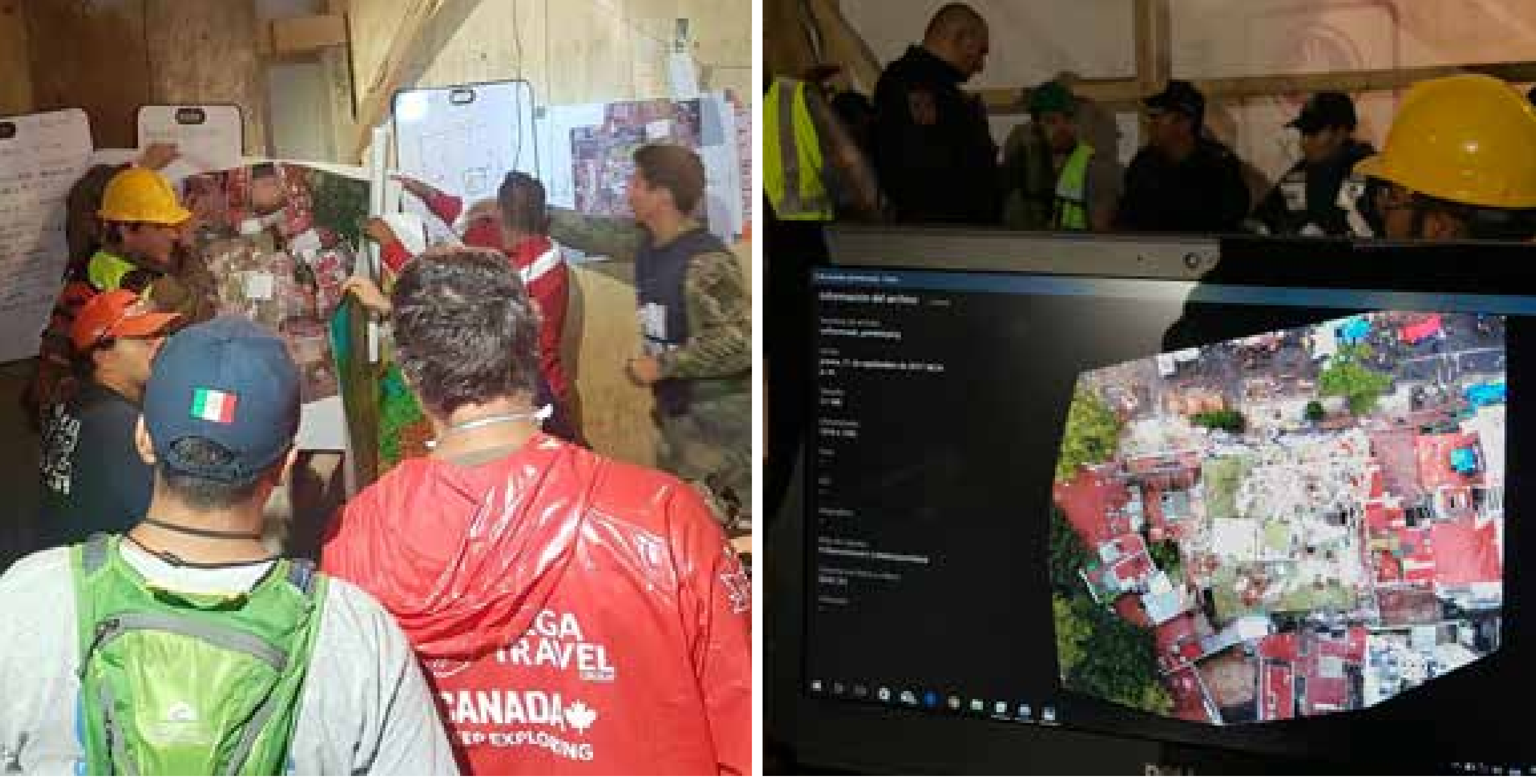


Advances in Drone Technology:
Flying Robots

Drones, formally called unmanned aerial vehicles (UAVs), were for many years recognized largely for their defense applications. Dedicated tech enthusiasts and humanitarians across the developing world, however, have recently shifted this perception as they pioneer transformative UAV projects to improve mitigation and response tactics in disaster risk management (DRM).

Examples of such "drones for good" can be found in Africa, East Asia and the Pacific, and Latin America. These projects are actively proving the value of drones in addressing and resolving critical gaps in DRM: they have put power in the hands of town planners; enabled low-cost, flexible, and high-quality data acquisition; established open source work flows (OpenDroneMap); and promoted skill development.





Teams responding to the September 2017 earthquake in Mexico City consult aerial imagery provided by drones.
Photo: © Pedro Matabuena-Aidronix.

In our increasingly techno-dependent society, it is important to note that drones should not be considered a panacea. They undoubtedly offer benefits, but like any other service technology, they should be adopted in DRM projects to support existing tools, tactics, and work flows, and will prove most effective when they are in turn supported by an enabling environment within a strong and enabling regulatory framework.

Case Studies

Data innovations in Malawi

One of the world's poorest nations, with a population that resides mainly in rural villages, Malawi faces unique challenges. The health sector struggles to address a range of problems (high maternal mortality, malnutrition, malaria, HIV/AIDs, and cholera); and climate-related disasters like flooding and famine only exacerbate the country's fragile situation. In this environment, drones have begun to offer Malawi innovative, affordable, and replicable DRM solutions. In June 2017, Malawi became home to the continent's first drone corridor—a testing ground for UAV technologies established with the support of UNICEF. Through extensive testing, benefits have been proven in imagery, connectivity, and transport.

With the help of UAV imagery, landslide risks are being identified, water resources mapped, damage assessments conducted, and displaced populations measured. Before the use of UAVs in this region, such activities required traditional aerial imagery flights, which are not only costly but often produce obstructed imagery of lesser quality than drones'.

Pilot projects have also shown UAVs' potential in providing crucial post-emergency cell and Wi-Fi connections, which allow disaster response teams to communicate with one another and let people affected by a disaster contact family members or friends. Given the wide use of mobile phones and Internet for communications, the provision of instant Internet access represents an enormous possible contribution of UAVs in support of DRM.

Rural populations have further benefited from the introduction of drones for delivery purposes. Within rural areas, "flying robots" have helped make supply chains more efficient, reducing the necessity of complex and time-consuming journeys to deliver critical goods to hard-to-reach areas. Drones are also making medical testing for disease much simpler by facilitating rapid prognoses.

Finally, drones are enabling progress in machine learning within Malawi. Innovators making use of the drone corridor are currently feeding drone imagery to IBM Watson, which can identify different plants and seasonal changes through artificial intelligence and image recognition. Analysis of this imagery helps generate statistical data that can provide valuable insights into agricultural monitoring, food security, and climate change. Another machine learning application made possible by drone imagery is analysis of access to safe water sources or sanitation facilities (see box 1), in part to advise communities on potential cholera hot spots. UNICEF is currently testing the use of drones for this purpose in Malawi.

MSF cargo UAVs

A collaboration between Médecins Sans Frontières (MSF) and WeRobotics, a nonprofit organization working to provide robotics solutions in low-income countries, employs drones across the developing world to conduct last-mile delivery of critical medical supplies. These efforts aim to overcome delivery constraints posed by isolation, inadequate or damaged transport infrastructure, and time sensitivity.

The program's first success came in Papua New Guinea, where the Ministry of Health tasked the organizations with collecting tuberculosis samples. This project highlighted the need to address the lack of UAV regulation and acceptance. However, it also showed that blood, vaccines, anti-venom, lab samples, and Oxycontin could be delivered by drone. The development of 2 kg cargo emergency response kits has encouraged access to treatment and is also inspiring improved emergency communication tools.

For drones to be used effectively in delivering medical supplies in remote areas, several requirements must be met:

- There must be a limited team of operators.
- Operation must be automatic and simple.
- Maintenance must be reliable and easy to carry out.

These requirements are exceptionally manageable, but the lack of UAV regulations and acceptance has made it difficult for operators like MSF and WeRobotics to provide demonstrations within the real environment. However, as testing of drones to support the delivery of medical supplies continues, it is hoped that this tool will be more widely adopted.

Box 1. Drones and Machine Learning

Artificial intelligence (aka machine learning) can be trained to recognize certain objects in pictures through the use of classification algorithms. This ability is then applied to new pictures to automatically recognize objects shown in them.

Machine learning can be used to analyze access to and use of sanitation services (measured by Sustainable Development Goal Indicator 6.2.1—Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water). Once the computer recognizes what sanitation facilities look like on the ground, it can be used to map and analyze where they are located and how accessible they are.

A test case in Malawi showed that sanitation facilities could be recognized with a confidence level of 70 percent, but with more training the accuracy will improve.

Source: GLOBHE 2018.

Drones for earthquakes and telemedicine

Aidronix, a Mexican start-up dedicated to proving the potential of "drones for good," has been involved in several humanitarian endeavors using drones. After the September 2017 earthquake in Mexico City, Aidronix was able to detect unstable buildings by analyzing movements between drone flights, and officials used this information to rapidly support buildings that were in danger of collapse. Aidronix has also driven the adoption of drones for telemedicine—the remote diagnosis and treatment of patients—as a way to improve medical access for those in difficult-to-reach areas and potentially reduce complications during rural births.

Aidronix emphasizes the importance of having drone operators work together with emergency response teams. Where coordination is lacking,

Drone imagery taken before and after Cyclone Gita in Tonga. *Source:* National Emergency Management Office of Tonga.

drones may fail to provide critical support and instead become an overwhelming and obstructive presence. To ensure sustainable drone-driven emergency response, it is necessary both to work within existing regulatory structures and to advocate for the development of strong regulatory frameworks.

National Emergency Management Office of Tonga

On February 12, 2018, Tonga was struck by Cyclone Gita, the worst cyclone to hit the country since 1982. This devastating storm affected 75 percent of the population, destroyed 800 houses, and damaged 4,000 properties. Disaster response and recovery required understanding which communities were affected and to what extent. Far more affordable than satellite and aircraft interventions, UAVs were adopted by the National Emergency Management Office (NEMO) to enable rapid and repeated deployment over small areas facing destruction.

NEMO began to deploy drones on the second day after the cyclone struck. Drones covered 300 km^2 in six days after the disaster. With the imagery collected during and after the event (see figure 1 for an example), the government was able to conduct remote housing damage assessment, plan for school reconstruction, and validate insurance claims.

NEMO recognizes the benefits offered by drones but sees the need for improving the work flow required for UAV flights, particularly in time-sensitive emergency situations. Post-processing and analysis, for example, depend upon improved Wi-Fi connections and processing power. A more streamlined regulatory process would make it easier to acquire flight permission from Tonga's Civil Aviation Authority to ensure rapid response in future events.

Conclusions

Disaster risk management requires quick, effective, and localized solutions to complex problems—and tech enthusiasts and humanitarians are steadily proving the immense capabilities of UAVs within this realm.

In recent years, the Global South has served as fertile testing ground for such UAV-driven solutions. The case studies described here showcase how UAVs are being used successfully in DRM applications—but they also reveal some of the limitations of their usage. Prospective users of drones for DRM are encouraged to investigate related projects, so we can learn from each other and avoid making the same mistakes. The World Bank's (2017) guidance note on using UAVs in development projects is a good resource.

Progress in the use of drones will depend in part on the introduction of well-crafted regulations, something that drone advocates want policy makers to understand. With progress should come greater recognition of drones as tools that complement (rather than substitute for) the established tools and tactics of DRM.

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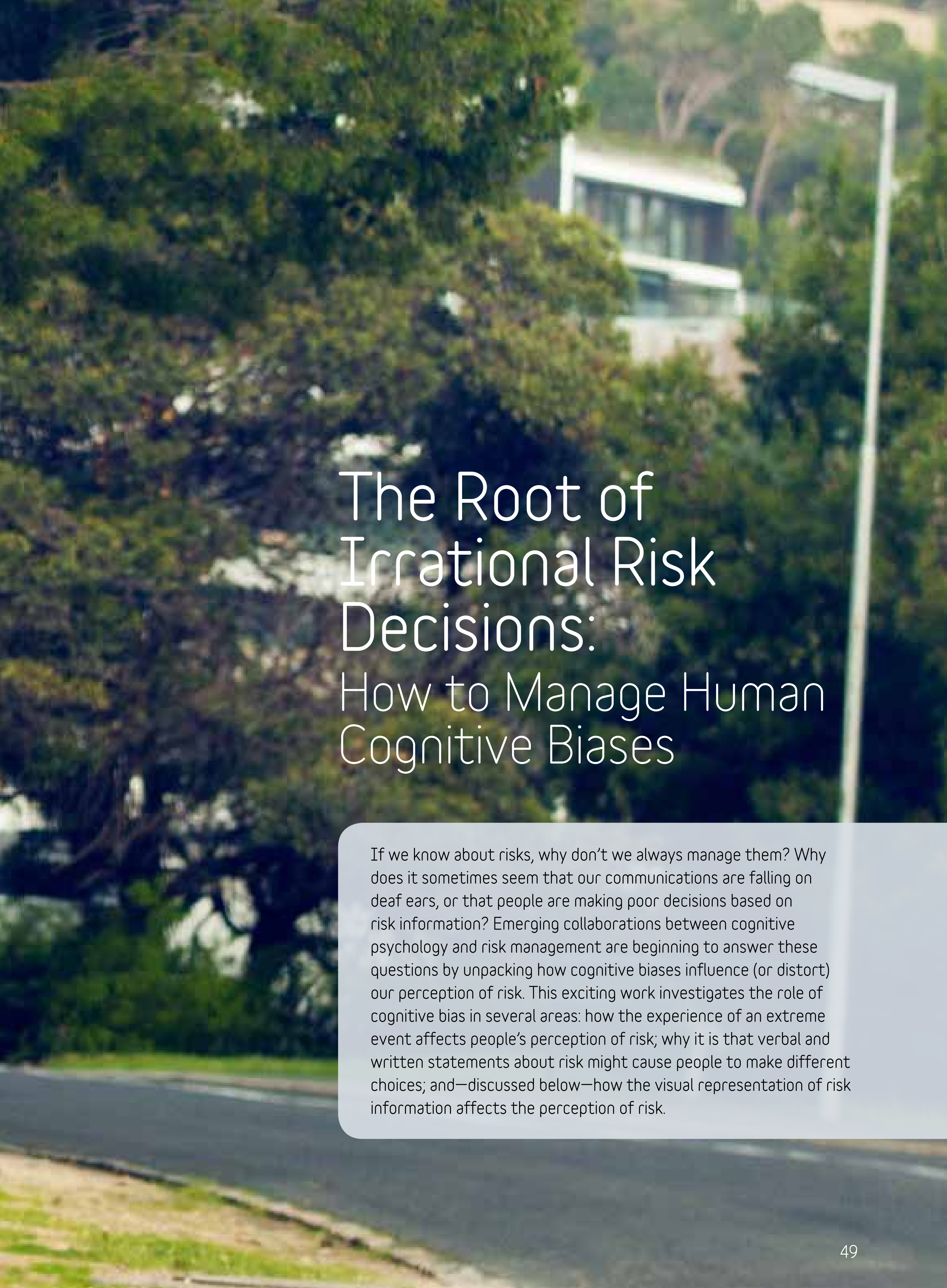


The Root of Irrational Risk Decisions:

How to Manage Human Cognitive Biases

If we know about risks, why don't we always manage them? Why does it sometimes seem that our communications are falling on deaf ears, or that people are making poor decisions based on risk information? Emerging collaborations between cognitive psychology and risk management are beginning to answer these questions by unpacking how cognitive biases influence (or distort) our perception of risk. This exciting work investigates the role of cognitive bias in several areas: how the experience of an extreme event affects people's perception of risk; why it is that verbal and written statements about risk might cause people to make different choices; and—discussed below—how the visual representation of risk information affects the perception of risk.

In this session on cognitive biases related to risk, we conducted an interactive discussion about specific risk communication and management techniques that encourage—or discourage—risk-informed decision making. We invited comments on practical approaches that can be used to communicate risk successfully, based on the psychology behind human perception and decision making.

Background and Concepts

The capacity to make intuitive and strategic decisions is described by a dual-process account of decision making, which suggests that we make fast, easy, and computationally light decisions (known as Type 1 Fast processing) by default, but can also make slow, contemplative, and effortful decisions (Type 2 Slow processing). "Rules of thumb" are used in Fast processing to automate decision making, and thus decrease processing steps, reduce mental effort, and hasten decisions. These rules of thumb are called "heuristics," and they are quite advantageous when they expedite accurate decisions. However, when we apply heuristics in the wrong contexts, they can lead to errors.

An example of misapplied heuristics is the perceptual phenomenon known as the McGurk effect, in which what we hear is influenced by what we see. The effect is evident when we watch two videos, one in which a person seems to repeat the syllable "ba" and one in which he seems to repeat the syllable "fa." In fact, the audio from the two videos is the same, but the speaker is moving his mouth differently. Changing what we see changes the way that we perceive sound.[1] This effect is a result of these quick-decision rules of thumb that we have learned for language. When it comes to speech, we are usually right to assume that the information we see matches the information we hear. We use both modalities together to understand what someone is saying. The problem arises when we apply the assumption in those rare cases in which it does not hold.

In risk management, too, there are numerous situations where heuristics can inappropriately influence our decisions. For example, communications about risk can be very easily misinterpreted based on how the information is presented. Session attendees experienced this at first hand in a short experiment about "anchoring"—that is, people's tendency to use a prior reference point (the "anchor") in making estimates. Our brief experiment demonstrated that contextual information, specifically a random number included in an account of heat waves, influences people's estimates of actual heat wave temperatures.

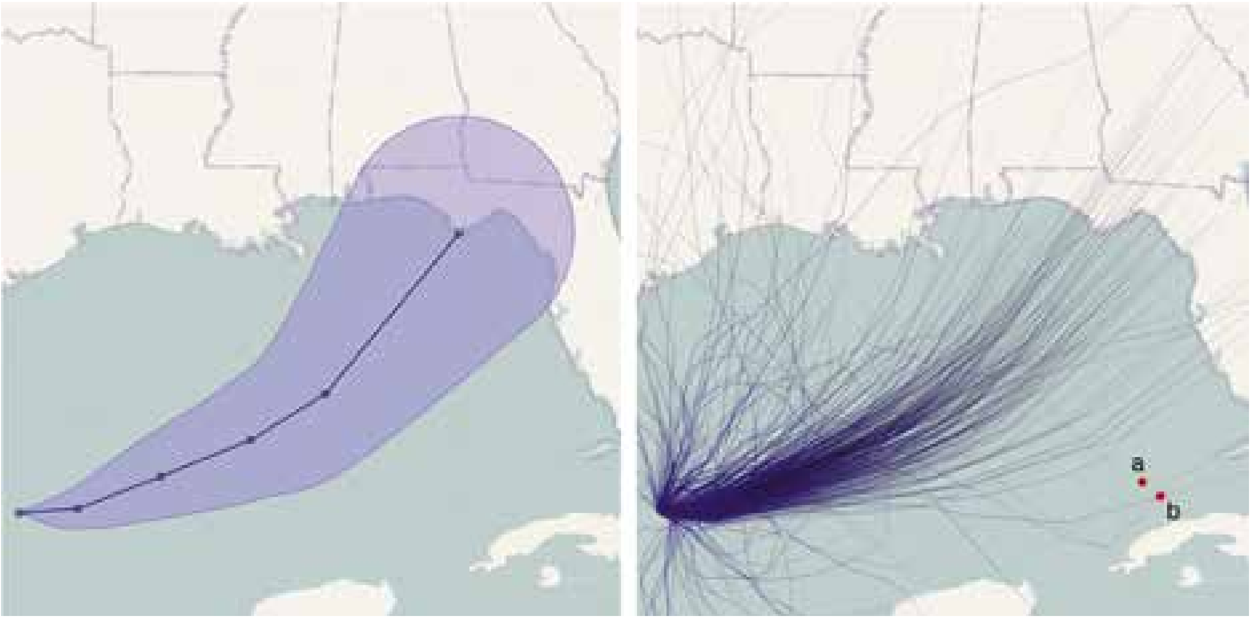
Case Studies

Our work has documented multiple biases in the visualization of data, for example in hurricane forecasting (Padilla, Ruginski, and Creem-Regehr 2017). Comparing multiple techniques for representing the uncertainty in hurricane path forecasts, prior work has found that the current technique used by the National Hurricane Center (cone of uncertainty, figure 1, left) produced more misinterpretations than an ensemble visualization of the same data (figure 1, right) (Padilla, Ruginski, and Creem-Regehr 2017; Ruginski et al. 2016).

As the ensemble hurricane forecast technique was unfamiliar to viewers, the researchers wanted to test if it had any adverse effects on decision making before fully endorsing it. They began by attempting to identify the heuristic that viewers used in looking at the ensemble display, with the goal of understanding whether and how the heuristic might lead to interpretive errors. They hypothesized that viewers were employing heuristics learned from using navigation applications like Google Maps, and that the individual ensemble members could be misunderstood as alternative routes that the hurricane could take, rather than the spread of uncertainty in the hurricane path. A deterministic route heuristic could lead to errors mainly if one of the ensemble lines directly hit a viewer's point of interest (i.e., her

[1] To try this yourself, view "Try the McGurk Effect! - Horizon: Is Seeing Believing? - BBC Two," November 10, 2010, https://www.youtube.com/watch?v=G-lN8vWm3m0.

Figure 1. Two techniques for representing the uncertainty in hurricane path forecasts: Cone of uncertainty (left) vs. ensemble visualization (right).



Source: Padilla, Ruginski, and Creem-Regehr 2017. Licensed under Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/).

county or town), in which case the viewer would be more concerned about the hurricane than if the line just missed the point of interest. According to an empirical evaluation, viewers believed that if an ensemble member hit their point of interest (figure 1, right; location b) there would be 24 percent more damage than if it just missed it (figure 1, right; location a).

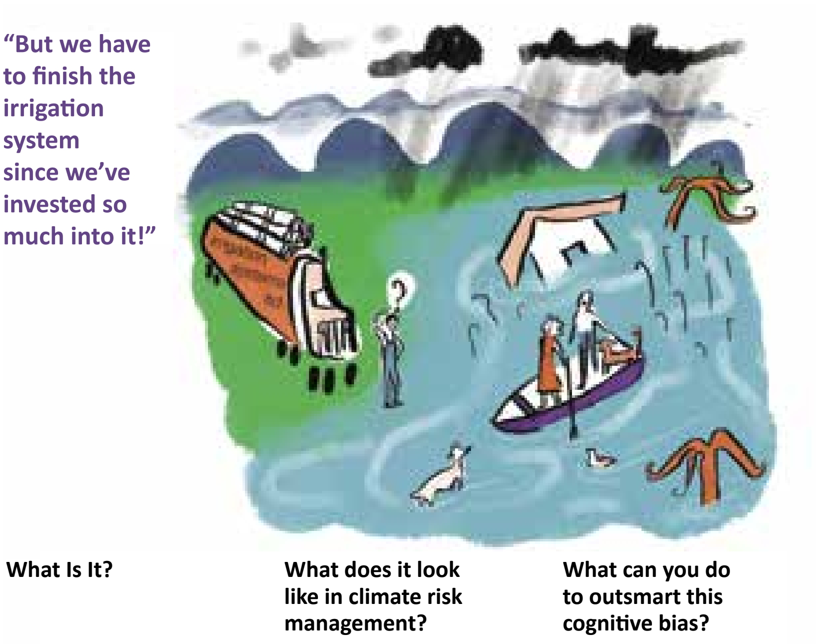
Having found that viewers believed each ensemble member represented a specific path that the hurricane could take, researchers then conducted a study to see whether increasing the number of ensemble members would affect viewers' interpretation of the data. It did: having more ensemble members reduced viewers' overestimation of damage by 61 percent. For example, if a map shows three ensemble members, one of which hits the viewer's town, the viewer might assume that there is a 33 percent chance that the storm will hit her home. However, a map showing 20 paths might lead her to conclude that there is only a 20 percent chance the storm would impact her. This is just one example of how an understanding of heuristics can drive changes in the presentation of risk information and in turn lead to better decisions.

Challenges

A key problem with human decision-making processes is that people are generally not aware of how they are making decisions. Because they are unaware of heuristics and decision-making rules, people do not attempt to avoid them in cases where they do not apply.

Take the example of confirmation bias, which is the tendency to look for evidence that *confirms* a theory. Researchers may unintentionally design their projects with this bias. For instance, in examining the effect of a humanitarian intervention, organizations often interview the aid recipients to assess how well they are doing. This approach tends to confirm that people are grateful for the aid they received, and that the items delivered were useful. However, organizations do not also interview the nonrecipients to see whether they are doing just as well in the absence of support.

Figure 2. The commitment heuristic—the tendency to continue supporting a decision in the face of evidence showing that such support no longer makes sense.



Source: Singh 2018; illustration by Rebeka Ryvola. ©BRACED 2018.

A major challenge is to help people become aware of these biases and find ways to avoid them—for example, through hypothesis testing and visualization testing.

Recommendations

Attention to the psychology of decision making can greatly improve our ability to understand, communicate, and manage risks. In this session, the organizers provided a space where scientists and risk managers could connect with those who study the psychology of decision making and develop collaborations to improve their work. One such collaboration has already yielded a set of infographics on several cognitive biases in risk management (Singh 2018); a sample is shown in figure 2. We recommend further in-depth study of risk management materials and projects to highlight common misconceptions and areas where small changes could make a big difference.

Conclusions

After this packed interactive session at UR2018, it is clear that the disaster risk management community is itching to learn more about improving risk communication and management through a fuller understanding of the psychology of decision making. Further research and collaboration in this growing area will support better tools and products to ensure that those at highest risk accurately understand their situation and what can be done to improve it.

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"UR is the best embodiment of how serious work can be joyful."

Photo: volk65

A Conversation on Geoengineering:
Altering the Planet, Envisioning Risk Financing Mechanisms

Using innovative, interactive approaches, this UR2018 session drew from science, policy, and art to offer participants a tailored introduction to solar geoengineering—including a creative visual overview of one of its most discussed technologies, a consideration of ethical and governance challenges, and last but not least a look at the implications of geoengineering for disaster risk managers, researchers, donors, the private sector, and other stakeholders.

What Is Geoengineering? Scientific Concepts and Governance Challenges

Geoengineering is commonly defined as deliberate, large-scale intervention in the global climate system to help manage and reduce climate change risks. This increasingly feasible technological option was once seen as crazy and taboo but is now gaining momentum. In response to a rapidly changing climate, the insufficient international response to date, and the growing risk of extreme events and slow-onset crises like sea-level rise, one option currently under consideration is a type of solar geoengineering—that is, dispersal of a small volume of aerosols into the atmosphere (for example via high-altitude jet) in order to reflect a small fraction of incoming sunlight back to space, thereby temporarily cooling the planet and partially counteracting some negative effects of global warming.

The consequences of this approach are largely unknown. Current analyses are based on computer models and analysis of the impact of volcano eruptions. Likely impacts include the intended decrease in global temperature, but also strong impacts on precipitation (large-scale volcano eruptions decrease global rainfall, for example). Solar engineering also has very different impacts across regions and activities, which create strong redistribution of climate benefits and risks, thereby scrambling the roster of climate "winners" and "losers." Even in one place, some people may benefit from reduced temperatures while others lose from changed precipitation patterns. Finally, one major issue with aerosol-based solar geoengineering is the fact that particles do not stay long in the atmosphere, meaning that this approach would require a continuous dispersion of aerosols to maintain the world temperature. If solar geoengineering is used at scale and the dispersal is interrupted, the temperature would rapidly rise again to the approximate level it was originally, creating massive, grave risks for ecosystems and life as we know it today.

Solar geoengineering is envisioned as a complement to conventional emissions reduction and adaptation measures, and never as a substitute for them. In addition, since solar geoengineering does not remove carbon from the atmosphere, any potential deployment would also require large-scale use of carbon removal technologies—along with a radical reduction in emissions and enhanced adaptation—in order to credibly address climate change.

Solar geoengineering has major implications in terms of disaster risks, from local to global levels, in areas ranging from research and modeling to governmental policies and risk financing. Solar geoengineering has the potential to provide considerable benefits in terms of disaster risk reduction, but also to exacerbate existing risks and create new ones.

The technical side of solar geoengineering is actually the easy part. More challenging is how to equitably govern an emerging technology with planet-altering impacts. Whose hand would be on the global thermostat, making the decision about if—and by how much—we should seek to cool global temperatures? And under what process would such a decision be made?

Would the world's poor and most vulnerable—those who currently suffer first and worst from climate change—have a fair say in whether this technology is deployed? After all, they would be affected most by any potential use. How would their voices be brought into the decision-making process? What about future generations: how could we take their welfare into account? And how would those who lose rather than benefit from deployment of solar geoengineering be compensated? Is there even such a thing as fair compensation under these circumstances? How might these complex issues be addressed in the real world of political horse-trading and power politics where decision making is far from perfectly rational?

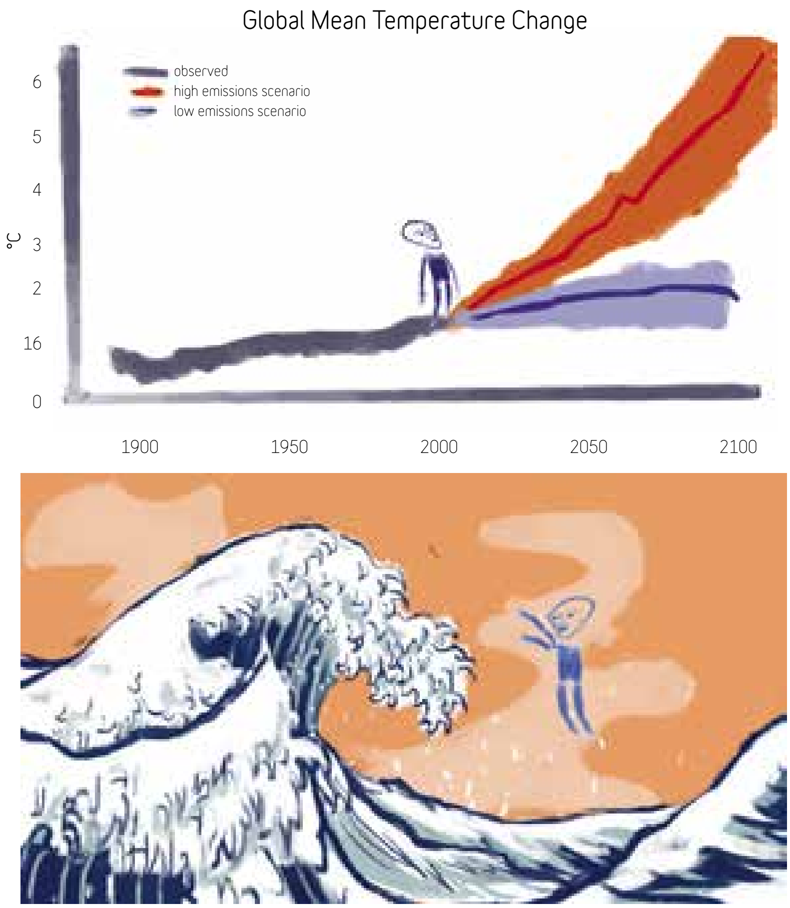
At present, there is no comprehensive, coherent set of international frameworks for governance of solar geoengineering. This situation poses a serious risk in and of itself, as a state or even a nonstate actor could potentially deploy solar geoengineering in the not-too-distant future without adequate information on potential risks and benefits—and without a transparent discussion, let alone agreement, by the international community. The ethical, governance, environmental, and geopolitical implications of solar geoengineering need to be openly discussed by all sectors of society, including those currently working to minimize disaster and climate risks.

So far, however, the Understanding Risk community has largely been absent from geoengineering deliberations. Geoengineering may be perceived as too theoretical, too complex, and not imminent enough to merit attention. However, early engagement by the sector is imperative to ensure that humanitarian and development considerations are integrated into policy decisions that will shape the future of disaster risks.

Innovations in Solar Geoengineering Communication

Fully embracing the "communicate," "disrupt," and "influence" themes of UR2018, this session took an unconventional approach to sharing the basics of geoengineering, including distributing printed copies of the UR geoengineering crossword puzzle (see pp. 60–61). After welcoming remarks by the moderator and a short presentation on basic concepts and prospects, participants were shown two art-infused short videos.

Figure 1. A Munch-inspired figure appeared in the short video mashing up IPCC data (top) and famous works of art (bottom).



Credit: Suarez, Ryvola, and Mendler de Suarez 2018.

The first video was an animation that blended scientific graphs from the Intergovernmental Panel on Climate Change (IPCC) with recognizable works of art, such as Monet's *Woman with a Parasol,* Hokusai's *Great Wave off Kanagawa,* and Escher's *Day and Night*. The video conveyed the basics of solar geoengineering in four minutes. The character weaving the narrative together was adapted from the human figure in Edvard Munch's *The Scream* (figure 1).

The second video, also four minutes long, drew on poetry and specifically Shakespeare to ponder the prospect of deliberately reflecting sunlight to cool down the planet. It showed literary performer Regie Gibson reciting "To geoengineer or not to geoengineer" (figure 2), a deliberate modification of Hamlet's soliloquy that captured key questions about a difficult and possibly imminent choice.

Figure 2. To geoengineer or not to geoengineer, that is the question posed in a short video shown at the UR2018 session on geoengineering.

Credit: Gibson et al. 2018.

Explorations in Index Insurance

Global warming will have uneven regional climatic effects, and so would solar geoengineering. During this session, some initial ideas were presented on financial instruments that could be applied to compensate for the side effects of geoengineering, with index-based insurance being one example.

Discussion

In order to elicit questions and insights from participants, the session broke into parallel discussions among four groups: (1) science and technology, (2) governance, (3) index insurance, and (4) communicating geoengineering through art.

When the topic of geoengineering is introduced to a new audience, it elicits a broad range of powerful reactions. The prospect of deliberately manipulating the global climate is frightening, if not repellant, to many people. One common response is to suggest that even raising the topic of geoengineering may deter efforts to mitigate emissions or adapt to climate change (also known as moral hazard); another common response is concern about the portrayal of known and unknown risks. Both these reactions were evident among session participants.

The group that focused on index insurance was particularly lively, with strong opinions expressed about the ethics of geoengineering, the wisdom of global-scale climate interventions, and the moral hazard of pursuing geoengineering at the expense of arguably more pressing policy priorities. Given legitimate and widely shared concerns about the stakes involved in seeking to deliberately alter the climate, some exchanges were understandably intense. The session nonetheless enabled participants to communicate their views, opinions, and anxieties about this increasingly unavoidable topic.

The group that focused on communicating geoengineering through art was also lively. Members of this group shared their thoughts about the animation and the poetry video; one common thread was that art had the power to activate people's emotional core, and that the films had made the ethical elements of geoengineering decision making truly personal. The vivid visuals, compelling sound, and emotional language were intended to bring questions around geoengineering close—almost uncomfortably close—to the viewer. Participants pondered, "Would it have been possible for people to connect so deeply to the issues had the films not primed them? Would the session instead have been characterized by high-level, philosophical, and mainly rational discussion?" The session ended in agreement that poetry, film, and other forms of creative communication have an important role to play, especially when the issues are abstract, the stakes are high, and the goal is to promote comprehensive deliberation and discussion.

Importantly, while previous geoengineering events have mostly engaged climate scientists, governance experts, environmental activists, and other stakeholders, this session was, to our knowledge, the first time that geoengineering was brought to the disaster risk management and financing community—and also the first time that the emotional dimensions of risky decisions were intentionally elicited through art. Not surprisingly, the intensity of the discussions matched the gravity of the issues at stake.

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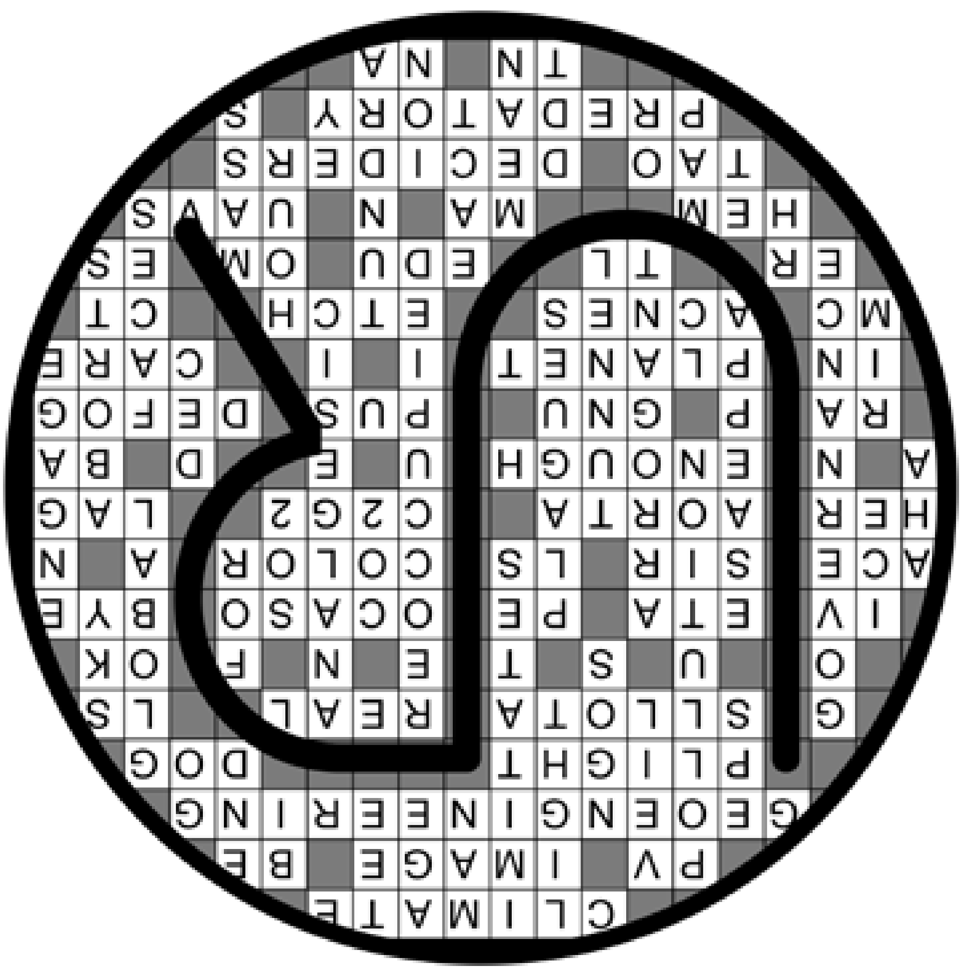
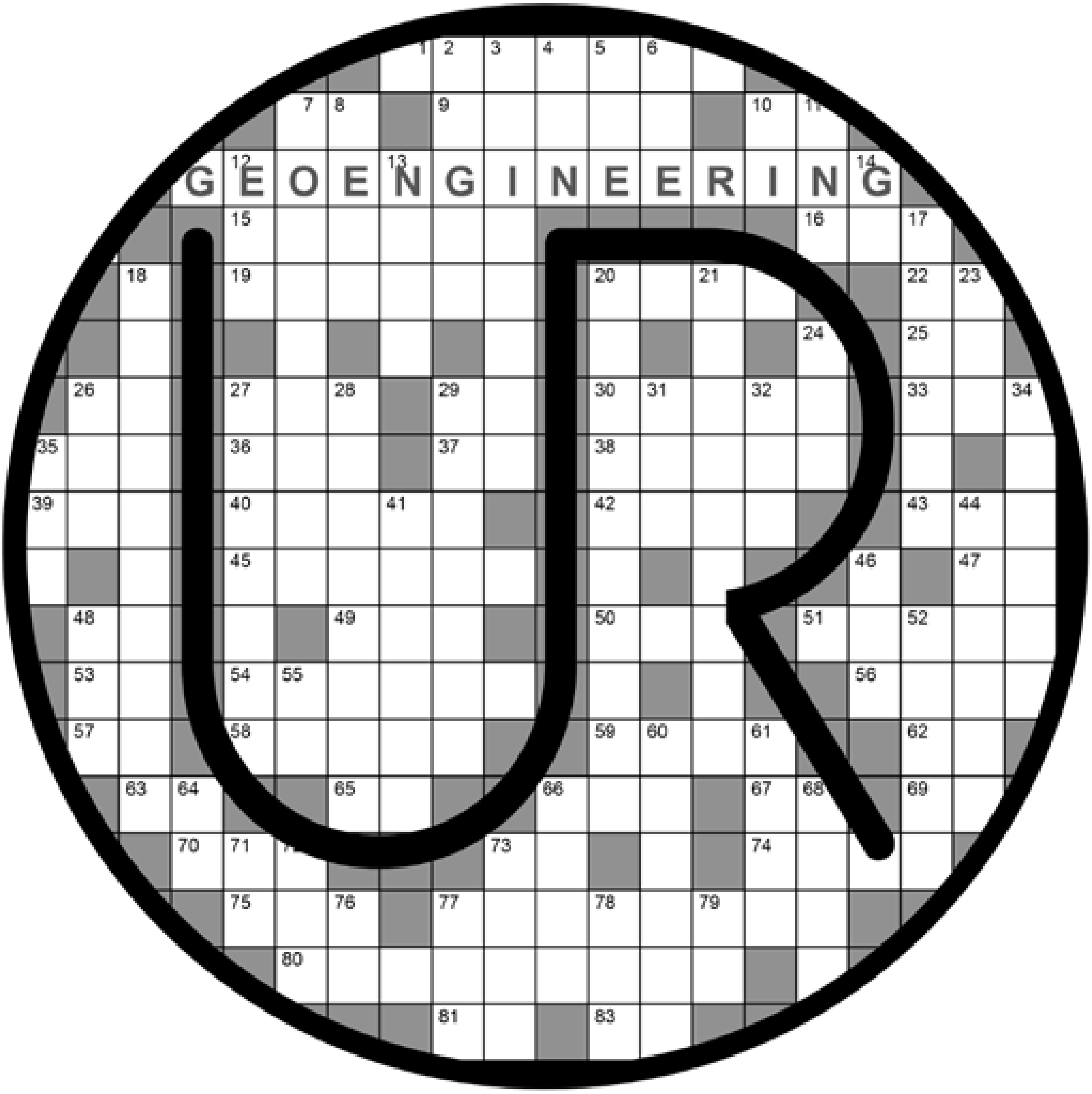


Answers to crossword puzzle featured on pp. 60–61.

ACROSS
1. It's changing, needs fixing
7. Solar way to make electricity. Good for decarbonizing
9. Worth a thousand words
10. To ___ or not to ___ (relevant for geoengineering)
15. Dangerous, difficult situation
16. Barking pet
19. esir level aes yb denetaerht ,sdnalsi feer depahs-gniR
20. Not fake
22. Least Squares
25. Fine
26. Four
27. Estimated time of arrival (for geoengineering, we don't know...)
29. Performance evaluation
30. 'Sunset', in Spanish
33. Adios
35. Highest card
36. Option for addressing a gentleman
37. Light speed
38. Visual attribute of things
39. Belonging to a lady
40. Blood leaves the heart through this artery
42. Carnegie Climate Geoengineering Governance Initiative
43. Delay
45. Sufficient
47. Bachelor of arts
48. Egyptian Sun God
49. Large antelope
50. Yellowish goo resulting from infection
51. Remove condensation from windshield
53. Not out
54. "The ___ Remade", a geoengineering book. Also, satellite company
56. Serious, kind concern to avoid risk. Should drive geoengineering debates
57. Master of ceremonies
58. Many pimples on the face (plural)
59. Engrave
62. Technology for communication
63. Room where you go in emergencies. There isn't a planetary one...
65.Thallium
66. University emails often end with this
67. The sound of meditation
69. 'It is', in Spanish
70. Sewn edge of cloth
73. Mother
74. Drones. Could eventually be used for deploying 32 down in the stratosphere
75. The Way, combining Yin and Yang
75. Forces something into place
77. Those who define what to do. For geoengineering, who shall it be?
80. ____ Geoengineering: seeking to benefit self at the expense of others
81. Ton
82. Sodium

DOWN
2. Visible solar energy. Geoengineering would dim it
3. Geoengineering _____ explosive volcanic eruptions
4. Cause of the Anthropocene
5. Era
6. A target in certain games
7. Presence of harmful substance
8. A fine layer used to prevent light from passing
10. Preface for two
11. Goal
12. Ensemble prediction system
13. Non-governmental organizations
14. Last board game to see humans lose to machines
17. _____ Warming: What geoengineering aims to address
18. Manner of setting policies and actions
20. bsorbed n orrying houghts
21. Substance that relieves pain
22. Extra large
23. Atmosphere and outer space, seen from Earth
24. In support of
26. Solid water, rapidly dwindling in the Arc<c
27. yfsitas ,eveileR
28. Pompous
30. Contagious diseases that spread fast
31. This gas, added to the atmosphere, is heating up Earth
32. This gas, added to the stratosphere, can cool down Earth
34. Become involved. We need to ___ in geoengineering
35. Abrupt awareness
41.[2 Down] at the end of the ____
44. Ends before completion
46. Before Jan
48. Circular edge
52. Confronts
55. Low carbon
60. Arctic region, can release methane & speed up warming
61. Sixty minutes
64. Blood factor
66. Pecise, acurate, crrect
68. E / c2
71. "That's ___!": same as 45 across
72. Flat depiction of all or part of Earth
73 Average. Unfair
76. To geoengineer ___ not to geoengineer? The time to face this choice is coming near
77. Insecticide
78. Charged molecule
79. Execution year


GEOENGINEERING


Graphic: shulz.

Cyber Risk in Light of Technological Innovation

Technological innovation presents immense development opportunities and has become an increasingly significant area of activity in developing countries. Digital tools have been proven to generate economic growth, and they can help developing countries overcome a lack of various traditional infrastructures. But in addition to these benefits and opportunities, technological innovation also brings risks.

Cyber risk can entail the risk of financial loss as well as disruption or damage to a country's economy, infrastructure, or reputation as a result of damage to its digital technology systems in the face of malicious attacks. The magnitude of cyber risks can be significant and comparable to the risks posed by disasters and armed conflicts. There have been numerous cyber incidents in developing countries in recent years. To name two: in 2016, hackers in Bangladesh intercepted $80 million in bank transactions (Al Jazeera 2018); in 2017, malicious hacking in Kiev, Ukraine, caused a widespread power shutdown that spread chaos in the capital (NPR 2017).

To assist developing countries in generating the local capacity and cyber-protection institutions necessary to support government investments in technological innovation, cybersecurity must be promoted hand in hand with digital development. Indeed, identifying and understanding risks to cybersecurity is a crucial component of digital development.

The UR2018 technical session on cyber risk in light of technological innovation brought together representatives from government and the private sector to discuss innovations and best practices in understanding and protecting against cyber risk. Uriel Raviv, the economic attaché from the embassy of Israel, discussed cyber risk from a government perspective. Horacio Martín Contreras Ocaña Sr., an expert in information technology and telecommunications with Huawei, highlighted the challenges faced by private sector companies and described some approaches companies use to identify cyber risk. Two panelists working for private cybersecurity or technology firms, Emmanuel Ruiz of the Check Point Mexico and Javier Ethiel Sánchez Serra of MER Group Mexico, discussed methodologies for assessing cyber risk.

The panelists addressed how to define cyber risk, as well as how to identify it. They emphasized that cyber risks are no longer a problem of the developed world alone, but also threaten developing countries, which may be pushed into crisis conditions if a significant cyber risk becomes a reality, as occurred in Kiev and Bangladesh. The panelists discussed foreseeable trends in cyber threats, the latest tools available to cope with these threats, and the importance of building awareness about them.

Key Messages

A number of key messages emerged during the technical session:

- *All countries are vulnerable to cyber risks.* Cybersecurity is often perceived as an issue for rich countries. But as the world becomes ever more digitized and digital technologies penetrate almost every sector, it is clear that cybersecurity is also a concern for developing countries, particularly those still working to develop systems for greater cyber resilience.
- *Cyber risks threaten development and belong on the development agenda.* Developing countries have many urgent issues confronting them but they cannot ignore the importance of cybersecurity. In a developing country, a cyberattack could harm fragile institutions, impede economic growth, and damage the financial sector. Developing countries must therefore establish or strengthen cybersecurity infrastructures. Steps toward this goal include promoting cooperation between agencies and institutions, fostering public trust in institutions, fostering cooperation by the public, developing necessary human capacity, and working to ensure private sector integrity.
- *Cyber risk preparedness is necessary.* As one panelist explained, the most effective strategies for protecting

To assist developing countries in generating the local capacity and cyber-protection institutions necessary to support government investments in technological innovation, cybersecurity must be promoted hand in hand with digital development.

against cyber risk balance technology, people, and processes. But even the most effective strategies cannot protect against risk completely. Just as there are drills and exercises to prepare for disasters such as earthquake, there should be drills and exercises to prepare for cyberattacks.

- *Governments have a responsibility to ensure cybersecurity but private companies and ordinary citizens should also be part of this effort.* Governments should consider cybersecurity as part of economic and national security. They need several key capabilities to address their most basic cyber protection requirements: a method by which private companies can easily share cyber threat information with them and with each other, a set of tools that citizens can use to protect themselves from cyberattacks; and a long-term strategy for cybersecurity awareness and protection as well as the ability to respond to immediate threats. In Israel, for example, the government established a strong centralized regulator (Israel National Cyber Directorate, INCD) that enjoys the trust of all sectors and is backed by the Prime Minister's Office. The INCD oversees an emergency cyber response team, which is expected to react if a major cyberattack is carried out against one of Israel's core sectors or facilities. It also acts as the regulator in matters of digital security, establishes relevant norms and rules, and works to ensure that both businesses and private citizens understand cyber risk and know how to protect themselves against likely threats.
- *Technical assistance can build cyber resilience.* Developed countries in general and the private sector in particular can help strengthen the ability of developing countries to address cyber risk. Specifically, they can help overcome limited human capacity and limited resources. Especially important is technical assistance to help governments retire, replace, and modernize legacy IT systems, which are generally difficult to secure and expensive. This modernization is a crucial step in reducing cyber risk. The World Bank can also play a role by promoting cooperation among countries to address some common cybersecurity challenges.
- *Citizens should be empowered to protect themselves.* Developing countries need help in promoting use of multi-factor authentication—moving beyond just passwords—and more generally in empowering citizens to secure their online accounts. For example, by judiciously combining a strong password with additional factors, such as a fingerprint or a single-use code delivered in a text message, citizens can make their accounts even more secure.

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Just as there are drills and exercises to prepare for disasters such as earthquake, there should be drills and exercises to prepare for cyberattacks.

Side Event

Green Walls: Using Nature to Manage Nature's Risks

Nature-based solutions (NBS) have significant potential to mitigate flood and erosion risks and contribute to climate resilience strategies in developing countries. Natural systems such as coral reefs, mangroves, and forests dissipate and attenuate flood waves, providing natural barriers that lessen the risk of flooding and erosion. However, the prominence of these systems has decreased significantly in the last century due to urbanization and environmental degradation. Rehabilitating natural systems has the potential to decrease climate risks while simultaneously creating jobs, improving the environment, increasing biodiversity, and promoting tourism. However, successfully implementing appropriate and sustainable NBS remains challenging.

In this session, our panel of global experts led a frank and open discussion about the opportunities and challenges associated with implementing NBS. Our panel—led by Mark Lawless of JBA and Brenden Jongman, Juliana Castano Isaza, and Stefanie Kaupa, all of the World Bank—provided unique insight into NBS-related studies around the world. Presentations addressed innovative new drone-based approaches being used in Tanzania to capture data supporting NBS initiatives (Aboud S. Jumbe, Department of Environment, Tanzania); new tools being used to classify coastal systems and support decision making globally (Lars Rosendahl Appelquist, Coastal Hazard Wheel); use of artificial reefs to protect against flooding and erosion and boost tourism in the Yucatán peninsula (Rodolfo Silva Casarín, Universidad Nacional Autónoma de México); and new partnerships using innovative strategies to finance coral reef restoration (Borja G. Reguero, Nature Conservancy).

These presentations stimulated a highly interactive exploration of key challenges to unlocking the potential of NBS. Some of these challenges related to data and tools:

- Participants agreed that the "minimum viable product" of risk assessments undertaken to support NBS is not well defined; the result is a lack of transparency and consistency in decision making.
- Despite calls for funding to support monitoring schemes for NBS, many projects do not budget for monitoring throughout the project cycle. This omission can reduce the effectiveness of NBS, which need to be managed in a dynamic and adaptive manner over long time scales.
- Gaps in quantitative data are still common and frequently filled with qualitative data. This approach reduces stakeholders' confidence in assertions about NBS and may perpetuate the focus on perceived "surer bet" solutions of concrete and steel.

Participants also identified challenges related to decision making and governance:

- Participants indicated that progress is being made in use of NBS, but also noted a

Young mangroves in Bang Pu, Thailand. Photo: Mumemories.

continuing bias among decision makers and practitioners toward conventional solutions, largely a function of capacity, knowledge, and institutional barriers. This bias permeates public discourse and affects perceptions of the effectiveness of NBS, resulting in greater risk aversion.

- While sustainability is at the heart of NBS, the benefits of NBS are realized over longer time scales than those of conventional solutions. These longer time scales are not always consistent with the decision making and disbursement time scales of governmental and donor agencies.
- NBS implementation and planning are complicated by a lack of coordination between authorities and by knowledge silos across hierarchies and space.
- It can be difficult for local administrative entities to use NBS in development plans; this is because effective NBS often take place across large physical areas that reflect the boundaries of ecosystems and functional natural systems.

Despite these challenges, our panel was hugely optimistic about the future of NBS and offered the following recommendations:

- Nurture awareness and capacity building among current and future practitioners. The concepts underlying NBS should be integrated into secondary and tertiary curriculums.
- Break down and distribute the financial risk associated with NBS. This is an essential step in helping decision makers and the public see past the short-term appeal of conventional solutions and overcome risk aversion.
- Step up communication of successful projects. Public awareness of successful NBS builds trust in their functionality, increases the political prestige associated with them, and ultimately creates demand.
- Foster change in current project cycles and development planning. Implementing and financing agencies should promote long-term planning and implementation frameworks such as phased and programmatic approaches that better reflect the time scales appropriate for NBS.
- Leverage hierarchical structures to establish a powerful and respected group as coordinator between institutions and agencies. This group should have the mandate and capacity to facilitate discussions on planning and implementation as well as the authority to demand decisions.

Participants agreed that they have a responsibility—collective and individual—to promote and drive these concepts forward, thereby nurturing transition to a new era of sustainable disaster risk management.

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Side Event

Is Migration Our Future? People in the Front Line of a Changing World

Throughout human history, changes in people's environments—arising from social, ecological, economic, or political pressures—have led to migration and displacement. Today, as the world's growing population faces more frequent and multidimensional risks, including economic and human rights inequalities, conflicts, environmental change, disaster impacts, and inadequate governance structures and processes, the scale of human flows, both within and across borders, is expected to rise. Such migration is often wrongfully perceived as a failure to adapt to rapidly changing systems, rather than as a coping mechanism and an attempt to maintain dignity. Just as disaster risk may drive migration, the mass incoming and outgoing movement of people may also significantly affect areas that migrants originate from, transit through, and arrive at as final destinations.

Migration, climate change, and social instability form a complex nexus that must be addressed in a holistic and innovative manner within the framework of disaster risk reduction (DRR). The UR2018 side event on migration focused on four areas: (1) environmental and socioeconomic drivers; (2) risks related to migration and displacement processes, and tools available for monitoring them; (3) current trends; and (4) the way and extent to which human mobility is addressed across relevant development agendas.

The moderators posed five questions to the panel, who shared their expertise and insight.

Question

What perspective is given to migration and displacement risks in the Sendai Framework for Disaster Risk Reduction?

Response from Rhea Katsanakis

The Sendai Framework recognizes disaster displacement as an important concern. It is crucial to integrate disaster displacement and other forms of human mobility into DRR strategies at all scales. To be effective, DRR and humanitarian assistance efforts need to address the risk and impacts of disaster displacement. They should also recognize that refugees and other people displaced by disasters or conflict, as well as the communities that host them, tend to have diminished capacity to cope with disaster impacts and manage future disaster risk.

Question

What can be done from the policy domain to mitigate and better manage migration and displacement risks?

Response from Katie Peters

Risk-informed development strategies and policies have the potential to reduce vulnerability and enhance abilities to cope with and respond to shocks and stressors. As many countries see migration as an adaptation strategy,

Photo: Suvra Kanti Das

migration arguably has to be supported much more strongly in national adaptation plans. Protections available to people affected by disaster displacement, whether they remain in or leave their country, should be strengthened.

Question

What are the links between the availability of natural resources and migration and displacement, and what can be done to monitor them?

Response from Samantha Kuzma

There is a strong connection between water and human security. In order to develop appropriate risk mitigation and adaptation strategies, access to risk information on the most vulnerable populations is crucial. Modern technologies and machine learning techniques can be used to develop early warning tools that will highlight the regions most vulnerable to water security–related threats.

Question

How can risk information improve our understanding of migration and displacement risks?

Response from Justin Ginnetti

In past years, the discourse on climate- and disaster-related displacement has been reframed from a risk perspective. This has helped create synergies between different policy agendas, but it has also called for more evidence on the number of people previously displaced, displaced at present, and at risk of being displaced in the future. We need to measure the risk of displacement in order to estimate future trends, and the tools developed for this purpose can be used to reduce risk, prepare for events, and identify responses to disasters when they do occur.

Question

How are migration and displacement risks captured across the 2030 development agenda?

Response from Jail Cruz

In order to fulfil the main goal of "leaving no one behind" when ending poverty, we need to take into account the numerous and complex interlinkages among the Sustainable Development Goals by balancing the three dimensions of sustainable development: the economic, social, and environmental. Poverty, environmental degradation, security, and other factors are drivers of both internal and international migration; migrants face several risks that must be addressed in implementing this agenda, with special attention given to human rights, gender equality, and the empowerment of women and girls.

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Communicate.

72 **Plenary** *UR Story: Narrative and Risk*

76 The Risk Information Value Chain: Data, Science, Narrative, and Action

83 Communicating Volcanic Risk: Lava, Eruptions, and Uncertainty

90 A Picture Is Worth a Thousand Actions: Communicating Earth Observation Data

96 Selecting the Best Satellite-Derived Risk Tool: Mining the Sky for Decision Making

102 Communicating Risk: Approaches for Parametric Insurance

108 **Side event** *The Interdisciplinary Pressure Cooker Event on Risk Communication: Supporting the Next Generation of Risk Communication Professionals*

110 **Side event** *Lights! Camera! Risk-Informed Action!: Making and Using Videos for Effective Communication of Risks and Good Practices to Address Them*


Remember when
In a lifetime
It would feel like
Like the last one
Think about a time

UR Story: *Narrative and Risk*

"No one ever made a decision because of a number. They need a story."

—Daniel Kahneman, 2002 Nobel Prize winner in economics

The field of disaster risk assessment is rife with numbers and analyses; evidence-based decisions that reduce disaster risk and enhance preparedness depend on them. But as crucial as they are, these numbers and analyses need to be communicated effectively to allow decision makers to take the best action possible. One way of communicating risk assessments effectively is to use narratives—stories that touch on the feeling side of our mental processes. After all, we humans are intuitive, feeling creatures just as much as calculating, rational ones. The psychological research used in behavioral economics tells us that we need to attend to both parts of our brain—and narrative is one way to tap into the intuitive, experiential, and emotional side that often drives our decisions.

Reason and Emotion in Decision Making

The use of risk assessments and decision analysis arose from a need to rationally understand and think about the world around us. But before we developed these analytical tools, we had our intuition, which humans have relied on since they lived in caves—for example, to determine whether an animal was dangerous. As humans evolved, "analytic thinking was placed on a pedestal and portrayed as the epitome of rationality. Affect and emotions were seen as interfering with reason" (Slovic et al. 2010, 23). In the disaster risk field, risk assessments—the analytic side of the coin—have come to dominate, but our emotions have been left out.

Over the past 50 years, extensive evidence has shown that humans process thoughts and make decisions in two different ways, referred to as System 1 and System 2 thinking (see table 1).

System 2 reflects the more deliberate, logical half of our brain that works more slowly and requires more energy and effort. This system is critical for analyzing disaster risk assessments. It is the source of our ability to process numbers and probabilities and to search for evidence to back up our decisions. For example, when risk assessments tell us that the probability of a 1-in-100-year flood occurring over a 50-year period is 39 percent, we must use our analytic, slower-processing brain to understand what that means. And even so, we aren't all that good at interpreting such information, or understanding what it means for our daily lives, unless we are true experts.

System 1 is our automatic, experiential way of thinking that involves intuitions and emotions. It is the feeling part of thinking. Because of System 1 processes, we do not see the world as it actually is, but rather through shortcuts that help us navigate the world. These shortcuts, known as heuristics and biases, help us answer difficult questions. One heuristic of direct relevance to risk is the "affect heuristic," which allows people to use emotions in making decisions and judgments. The affect heuristic suggests that when it comes to increasing the perception of risk, a strong emotional experience is important. This is where narratives come in.

Narratives appeal to our System 1 way of thinking. They put information into a quick and easy story for our brains to process, without requiring the strenuous efforts of System 2. We have seen the success of narratives in the fields of health risk (e.g., Janssen et al. 2012) and climate risk (e.g., Marx et al. 2007). Multiple studies in these fields—including studies of

Table 1: System 1 (Experiential) vs. System 2 (Analytical) Decision Making

System 1: Experiential System	System 2: Analytic System
1. Holistic	1. Analytic
2. Affective: pleasure-pain oriented	2. Logical: reason oriented (what is sensible)
3. Associationistic connections	3. Logical connections
4. Behavior mediated by "vibes" from past experiences	4. Behavior mediated by conscious appraisal of events
5. Encodes reality in concrete images, metaphors, and narratives	5. Encodes reality in abstract symbols, words, and numbers
6. More rapid processing: oriented toward immediate action	6. Slower processing: oriented toward delayed action
7. Self-evidently vivid: "experiencing is believing"	7. Requires justification via logic and evidence

Source: Slovic et al. 2010.

uncertain climate information—have concluded that people respond better to risk communication that joins statistical analysis with narrative, or in other words, to communication that speaks to System 1 and System 2 together. When information captures our emotions, it connects us with an experience that we can imagine ourselves in. Thus when narrative is done well, the affect heuristic comes into play. As the psychologist who "discovered" the affect heuristic and his literary critic son put it:

"The risk of global climate change, deforestation and biodiversity loss cannot be conveyed without presenting quantitative data—and yet these contemporary environmental phenomena can have little visceral, emotional meaning for the public unless they are also presented by way of stories and images" (Slovic and Slovic 2010, 81).

UR2018's Look at Narrative

To highlight the importance of good storytelling in efforts to support evidence-based decision making, UR2018 devoted a plenary session to narratives and risk.

Narrative, we learned, has helped make Romania more resilient and also helped reduce the impact of the 2017 Mexico City earthquake. One policy maker, one academic (who moonlights as a television host of science programs), and three journalists participated in the plenary session and explored why narrative is important in communicating risk, how narrative has been used in their own professions, and what makes narrative work.

With a high seismic risk and a populace that is ill prepared for the next big seismic event, Romania must meet the challenge of communicating risk effectively. Two presenters from Romania—Dr. Raed Arafat, Romania's Secretary of State for Emergency Situations, and Georgiana Ilie, a journalist for the magazine *Scoala9*—have both turned to narrative to meet this challenge.

Dr. Arafat has changed the way his country visualizes and describes disasters and emergency situations. Instead of relying on PowerPoint presentations or rote emergency drills, which fail to tap into our System 1 thinking, Romania now uses virtual reality to simulate what an earthquake in Bucharest would actually feel like. This innovative use of narrative creates a visceral, emotional reaction that prompts departments to be more prepared.

Ilie has also exploited the power of narrative to communicate risk. She recently wrote an in-depth, long-form article on just what would happen if a major earthquake hit the capital city. She helps her audience imagine themselves in the same situation as the protagonists, who (for example) walk in the street away from buildings in order to minimize the risk of being hit by falling debris from decrepit buildings and balconies. Ilie has heard from readers that they had never before considered this risk but will now remember how to avoid it should an earthquake actually occur.

In Mexico, another country with high seismic risk, narrative has also played a role in enhancing earthquake preparedness and response. Gabriela Warkentin, one of Mexico's leading journalists and academics, contrasted the 1985 and 2017 Mexico City earthquakes to highlight the role of narrative in improving earthquake response. She shared her experience in communicating information that was accurate and did not cause panic following the 2017 event. Both she and her colleagues used narrative to mobilize people and provide them with up-to-date information.

Insights into what makes good science and risk communication were also offered by Andrew Revkin, a science and environmental journalist at the National Geographic Society, and Iain Stewart, director of the Sustainable Earth Institute of Plymouth University. Each offered many examples of good storytelling, particularly about volcanos and being on the edge—literally in the water—of Victoria Falls. In making his point, Stewart borrowed from a paper on climate change communication: "Try to craft messages that are not only simple but memorable, and repeat them often. Make more effective use of imagery, metaphor, and narrative. In short, be a better storyteller, lead with what you know, and let your passion show" (Somerville and Hassol 2011).

Conclusion

Narrative is not a panacea or the only way of helping people understand their disaster risk, but it can be more effective than mere numbers. When narrative is done well and includes imagery and metaphor, it gets our brain to pay attention. Stories require less energy to process; numbers require more. Daniel Kahneman, the cofounder of behavioral economics who provides the epigraph to this summary, has remarked that "the understanding of numbers is so weak that they don't communicate anything" (quoted in Lewis 2016, 250). Instead, as Georgiana Ilie told the session audience, we need to "give people the opportunity to see themselves in…stories…, to identify with the heroes, to connect and feel powerful." The disaster

Iain Stewart on the UR2018 stage. Photo: Dominic Balog-Way.

risk community must move beyond providing just numbers. We will not be able to help the public, governments, and other decision makers understand their risk without drawing on the power of narrative.

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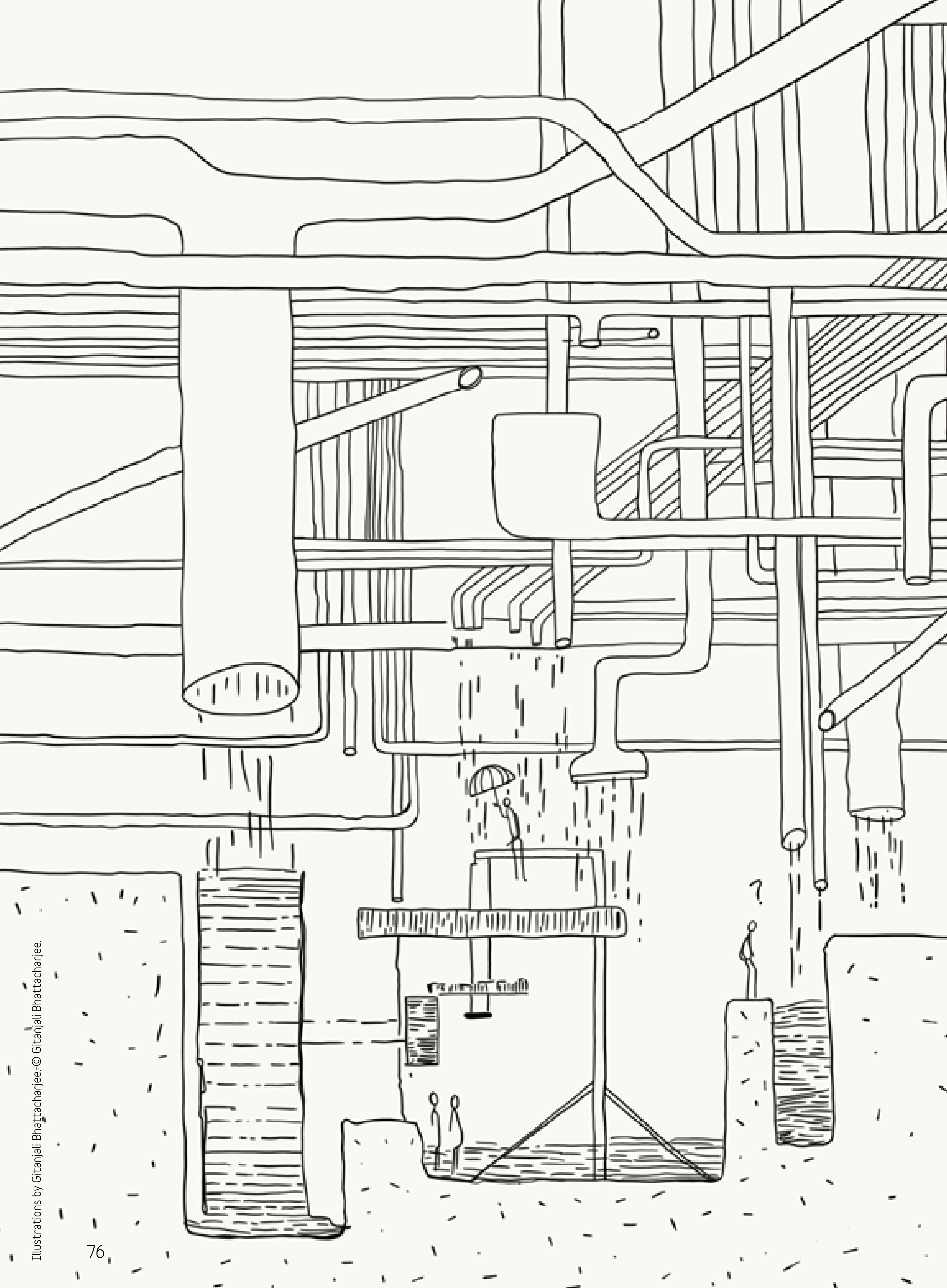

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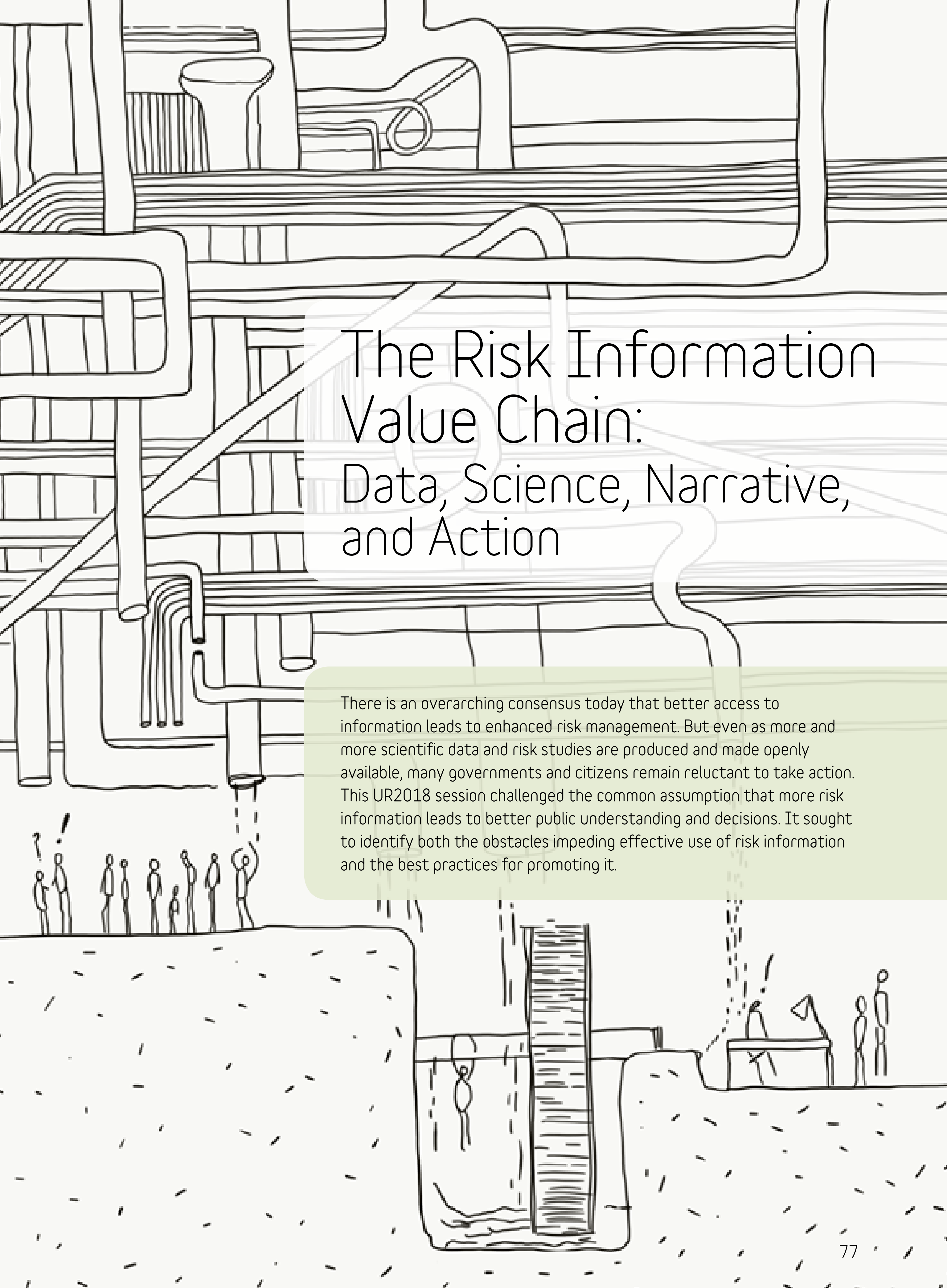
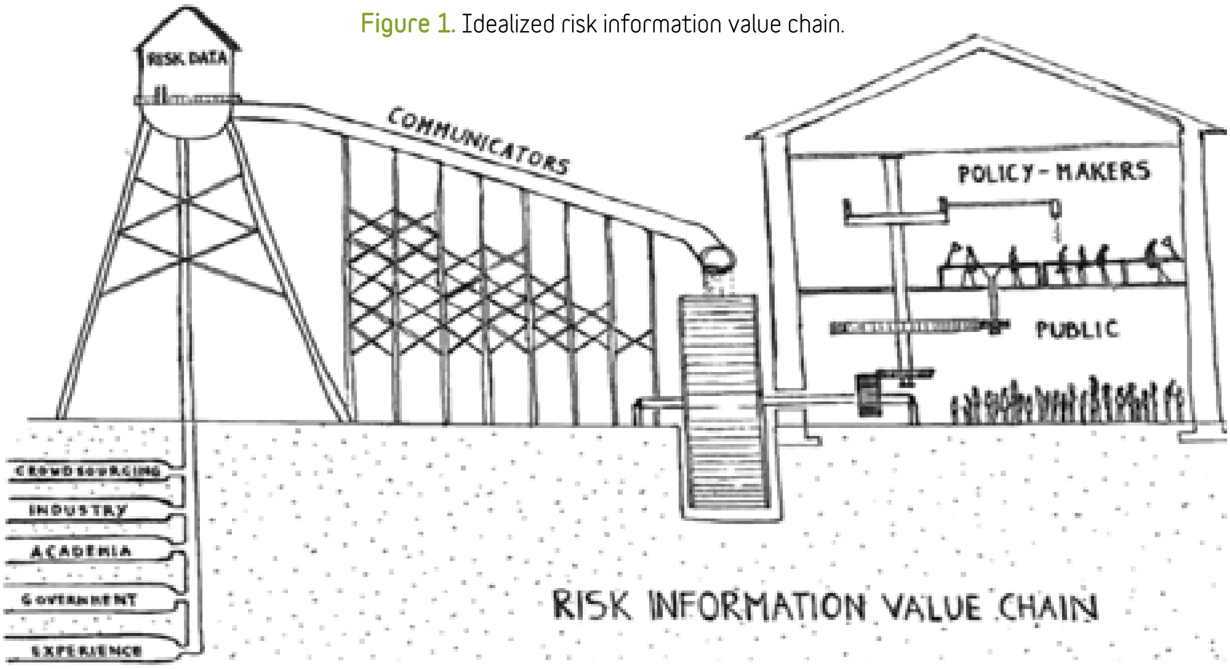


The Risk Information Value Chain:
Data, Science, Narrative, and Action

There is an overarching consensus today that better access to information leads to enhanced risk management. But even as more and more scientific data and risk studies are produced and made openly available, many governments and citizens remain reluctant to take action. This UR2018 session challenged the common assumption that more risk information leads to better public understanding and decisions. It sought to identify both the obstacles impeding effective use of risk information and the best practices for promoting it.

Figure 1. Idealized risk information value chain.



The Value of Risk Information

In the context of disaster risk management (DRM), risk information is the scientific and practical knowledge that can be used for emergency preparedness and planning, response and recovery, and cost-efficient risk reduction. On its own, risk information has no value; it gains value if it can support better decision making or favorably change people's behavior. In practice, such value is often not created.

This session used value chain analysis to shed light on the processes involved in creating risk information value. As illustrated in figure 1, in a risk information value chain, risk information is first created through scientific work, crowdsourcing, historical records, or other means; it then flows through data-sharing infrastructure, where it gets interpreted by experts or storytellers and communicated to the public and policy makers in the hopes that it will prompt risk-informed decision making and actions.

However, the case studies presented during the session show that the process of creating value from risk information is not straightforward, and often looks more like what is shown on the previous page. In real life, the drivers of action are often not transparent, and the avenues for data sharing and communication are sometimes unclear or nonexistent. Where decision makers and citizens receive information but don't know what to do with it, the result may be frustration and a lack of effective action, while scientists and disaster experts may feel that their results are not being put to good use.

Case Studies

Integrating risk information in policy making in Mexico City

Mexico City has access to and uses a number of risk data products, including the National Risk Atlas, National Climate Change Vulnerability Atlas, and Mexico City Risk Atlas. However, risk information does not appear to be well integrated in policy making. There seems to be a lack of awareness within the administration and among policy makers about how risk data can contribute. For instance, in 2005 a building-by-building earthquake risk model of the city was created, which included a real-time loss calculator able to provide outputs five minutes after an earthquake. Yet there is no evidence that this model has been used by the administration to plan for losses and financial recovery.

The importance of open data

The OpenDRI team from the Global Facility for Disaster Reduction and Recovery (GFDRR) has also faced and dealt with multiple data and risk communication challenges. During the 2010 Haiti earthquake, for example, no maps were available to help international organizations and the government respond. The 2015 Nepal earthquake strengthened the team's conviction that open data and the involvement of local stakeholders in the risk information process are key to DRM. Drawing on events in Nepal and elsewhere, OpenDRI developed a set of principles on how open data should be applied for DRM (GFDRR 2016).

Using games to communicate risk information

Experience suggests that using movies and games can be an effective way of communicating risk to citizens and changing people's behavior. The Art and Media Group of the Earth Observatory of Singapore is working with scientists to develop targeted documentaries and video games that speak to local audiences. One of the projects is *Earth Girl*, a casual game targeting a young audience that aims to increase awareness of disasters in the region (tsunami, flooding, and volcanic eruptions).

Measuring risk information's impact

BBC Media Action has stressed the importance of measuring the impact—the value—of the risk information we engage with. This approach requires in-depth audience research through surveys and post assessments. *Amrai Pari*, a TV show featuring methods of improving resilience that airs in Bangladesh, needed audience research to determine its effectiveness. Some 47 percent of the audience reported taking action after watching the show. This result was achieved thanks to a strong collaboration with multiple experts to make sure the content was accurate, practical, and responsible.

Challenges in Implementing Risk-Informed Activities

The session identified several challenges in implementing risk-informed activities:

- *Data sharing culture and incentives.* In many cases, risk data and assessments do not exist; where they do, information is usually scattered across different institutions and is not openly available. Reluctance to release data is often attributed to concerns over security and fears of political backlash. Moreover, when data are a source of revenue, there is little incentive for data sharing.
- *Actionable data and user involvement.* Not all risk information is useful for decision making. Regional risk assessments may not be useful for individual-building intervention, while the average annual loss is not a suitable input for emergency response planning. Furthermore, data sets are often created without user involvement or consideration of user needs, and as a result are often nonactionable. Lastly, data must be available at the time when users need it and at the right resolution—and these will vary with different DRM actors.
- *Skills and collaboration.* Effective interpretation and use of risk information require various skills from various disciplines. Necessary skills might include the ability to understand different hazards' characteristics, to analyze quantitative data and interpret probabilistic results, to tailor effective communication for different audiences, and to design interventions based on the results of risk assessments. While every individual in the value chain cannot possess all the necessary skills, each should at least understand and acknowledge the importance of other roles. This requires having the necessary partnerships, networks, or other channels in place for communicating and collaborating effectively.
- *Planning of communication.* The failure of risk information to prompt action may stem from a lack of necessary communication. There is currently an overemphasis on risk information products; but products must be part of an ongoing conversation with the intended audience, anchored in a strategic plan for change. This strategy for change should be integrated into a broader risk reduction plan, and not tucked under the banner of "information dissemination."

Opportunities and the Way Forward

The presentations suggest several opportunities for better action on risk information going forward:

- *Think about data as open infrastructure*. Perhaps the right metaphor for thinking about risk information is infrastructure. In *A Vast Machine*, Paul N. Edwards (2010) defined knowledge infrastructures as robust networks of people, artifacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds. In more concrete terms, this understanding calls for setting up proper standards, principles, and tools so that all people involved in DRM can collaborate and communicate more effectively. A key principle here is the need for open data. Tools such as the Open Data for Resilience Index and open source GeoNode data platform can help meet that need.
- *Pursue user-centered design of risk assessments*. To address the siloed processes of the risk information value chain, we need to take lessons from the user-centered design approach and apply them across the entire risk assessment process. Ideas surrounding user needs are often brought on at the end of the process (if at all), once the data have been collected, the models produced, and the reports written. OpenDRI attempts to address this challenge in *Design for Impact Framework: Integrating Open Data and Risk Communication for Decision-Making* (GFDRR 2018), a tool aimed at helping project implementers think through the design of risk assessment projects to ensure a tight handshake between the development of risk data and real-world decision making.
- *Improve the quality of risk communication*. There are three ways to improve the quality of risk communication: First, have a plan. Knowledge and information alone are not enough to drive change. We need to invest in research to understand the audience and identify the drivers of change that matter. This effort must go beyond demographics to understand the environments in which people operate and identify the barriers to and facilitators of change. Second, be creative. People are usually too busy with daily demands to engage deeply in disaster risk reduction. Relating risk reduction to what matters in everyday life—family, money, and fun—and using narratives and real stories can be an effective entry point. Finally, measure impact. What matters is not how many people we reach but whether these people think, feel, or do something differently as a result. We need to design and track impact measures to evaluate whether the communication strategy achieves the intended results.

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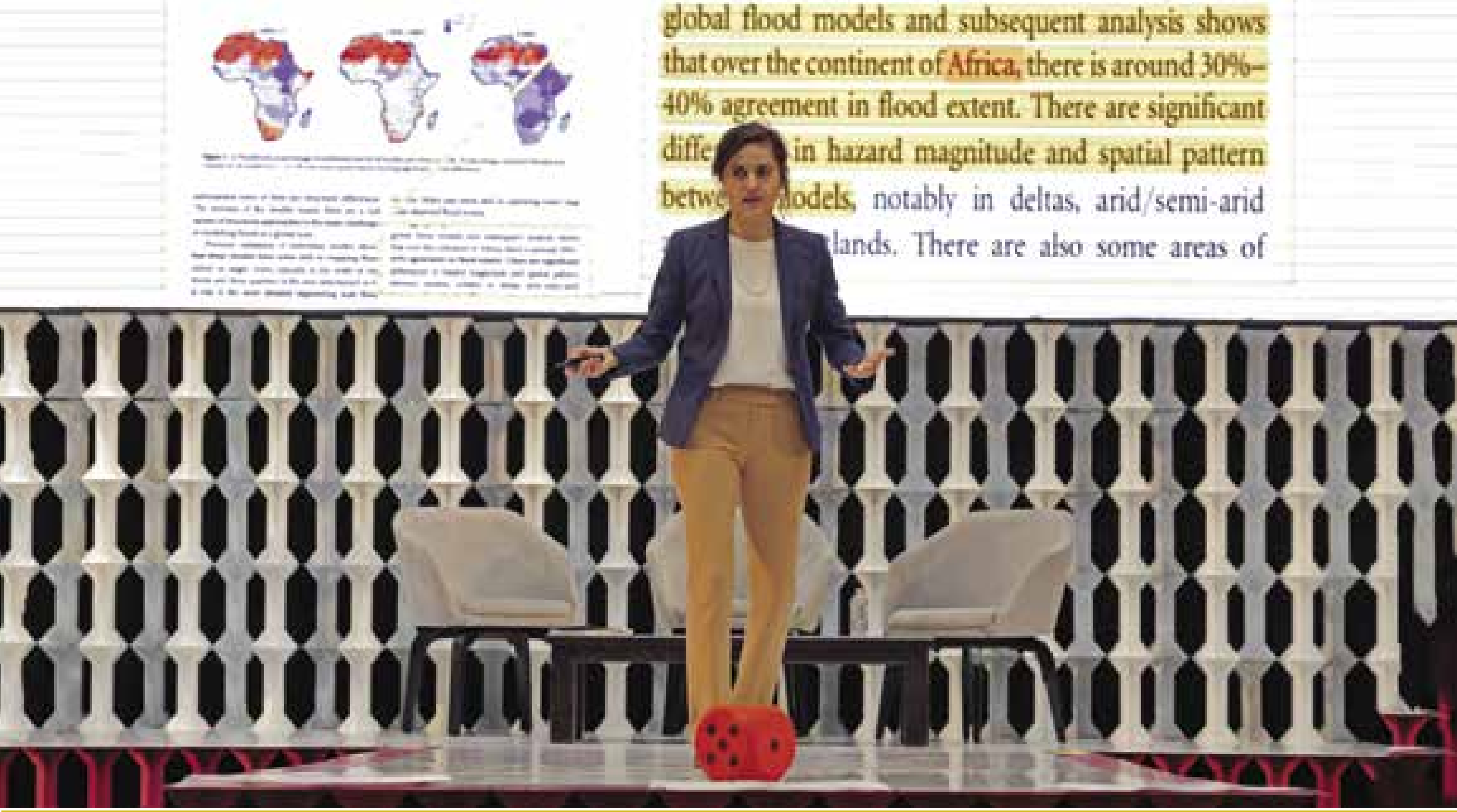
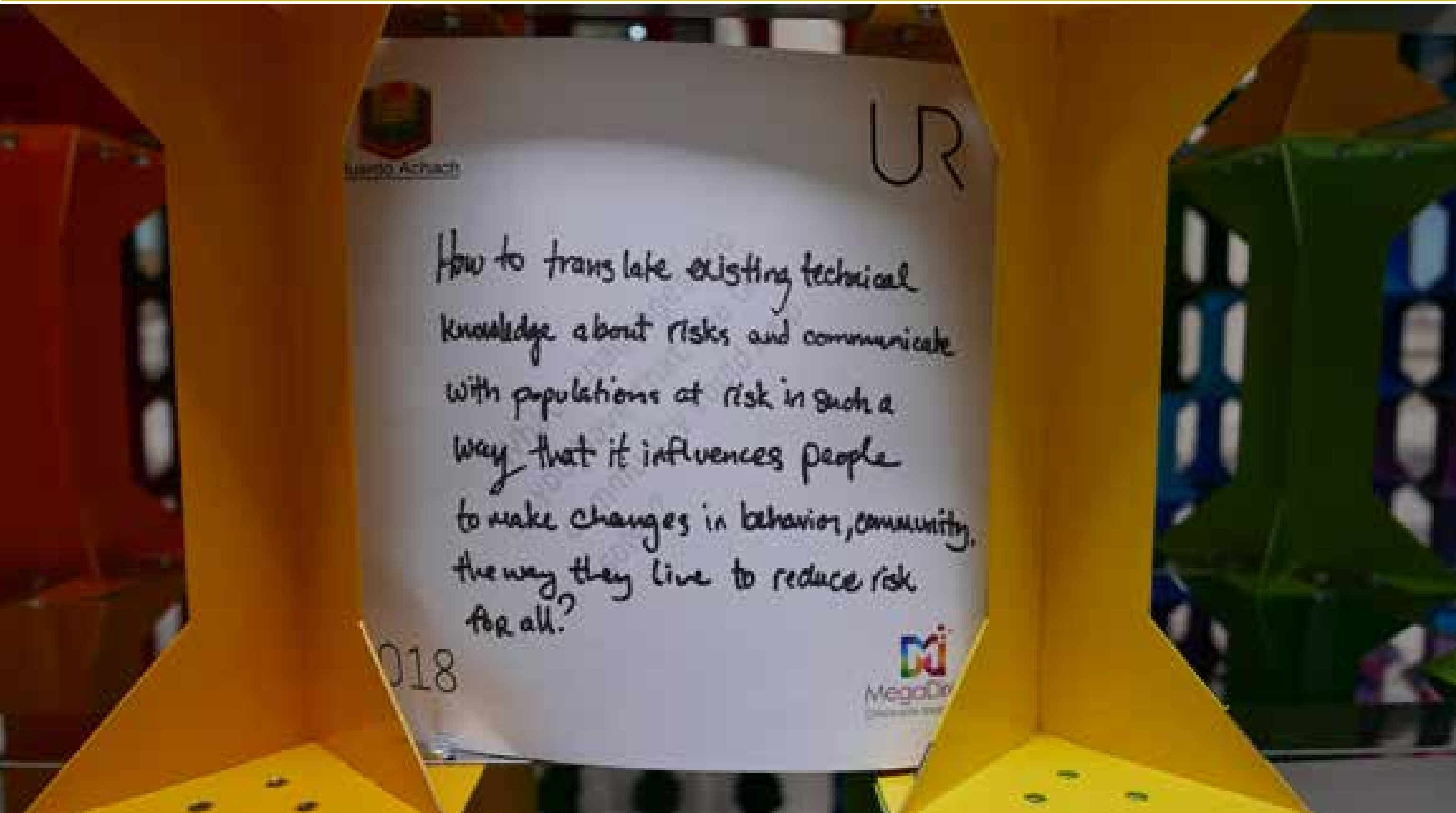


1,066 metal origami pillars were used for the stage.



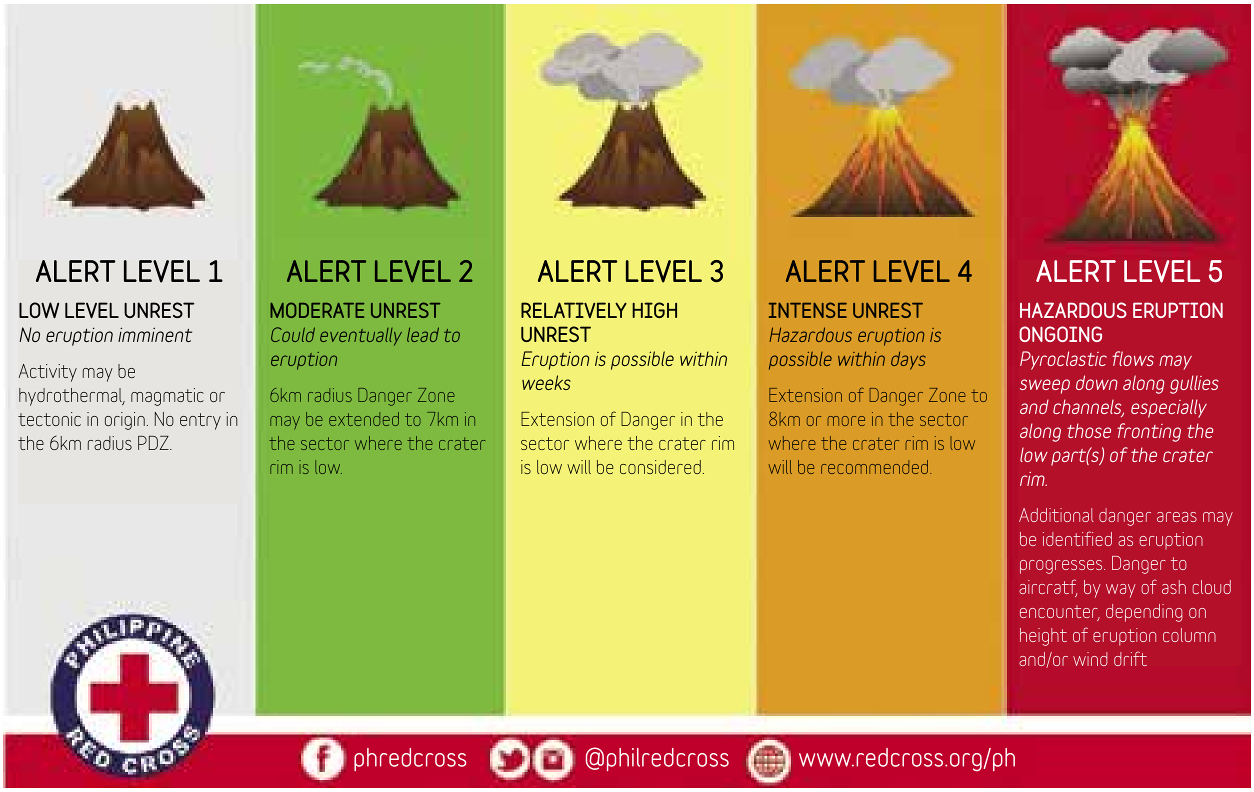
Chile, Puerto Varas, Calbuco volcano eruption. Photo: Gadaian.

Communicating Volcanic Risk:

Lava, Eruptions, and Uncertainty

Volcanic eruptions can cause devastating ash clouds, unstoppable lava flows, and even climate anomalies. In June 2018, the eruption of Guatemala's Volcán de Fuego claimed 159 lives and triggered the evacuation of thousands. Other eruptions on the Pacific Ring of Fire—in Indonesia, Hawaii, and the Philippines—also made the world's headlines in 2018. Such tragic events show that communicating volcanic risks to vulnerable communities is far from straightforward.

Figure 1. Volcano alert issued via Twitter by the Philippine Red Cross in collaboration with PHIVOLCS.



Source: Philippine Red Cross (@philredcross), January 17, 2018, https://twitter.com/philredcross/status/953559116835770369.

At what stage do experts turn caution into action? What does preparedness look like for eruption scenarios? When is the right time to evacuate? To answer these questions, scientists, decision makers, and media experts at UR2018 explored region-specific challenges, creative solutions, and real-life examples, both positive and cautionary, of communicating the risk of volcanic eruptions.

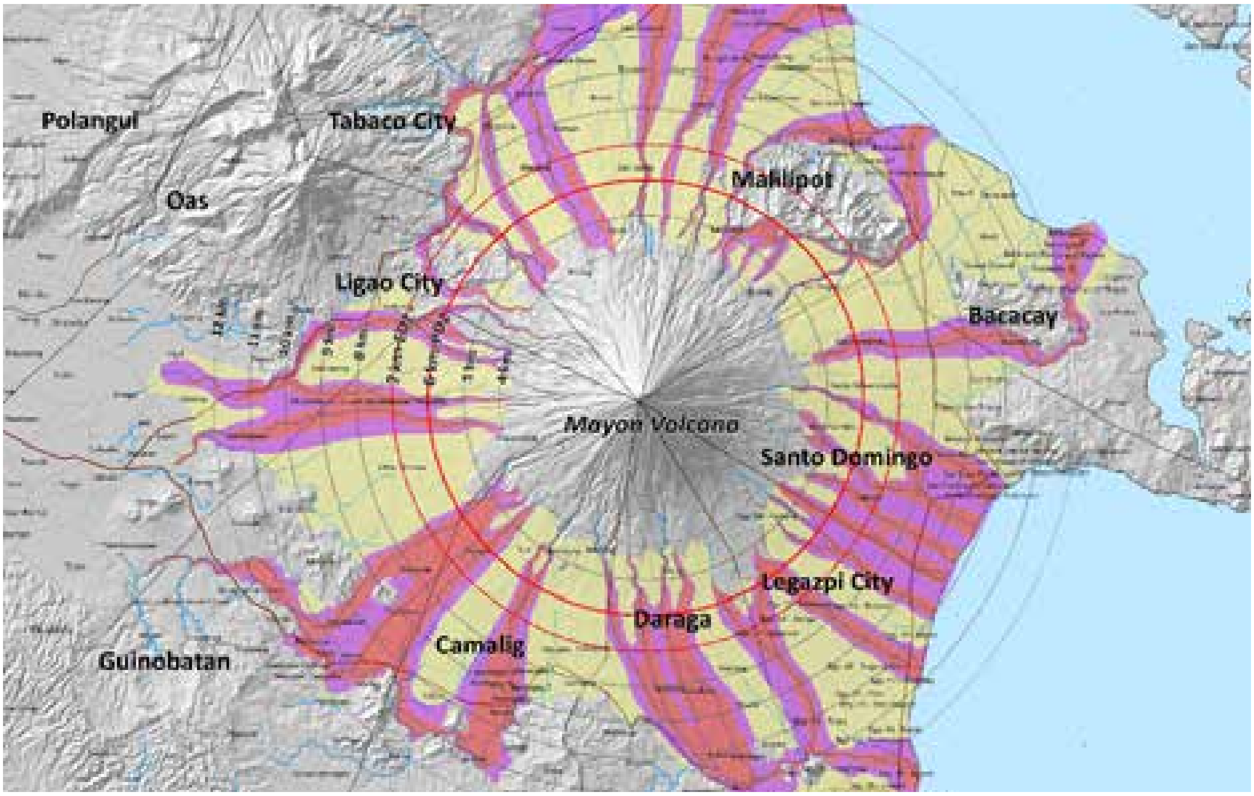
Philippines: "The Volcano (Always) Owns the Land"

The Philippines has 24 active volcanoes. Two in particular—Mount Pinatubo and Mount Mayon—have shaped preparedness and risk communication efforts by the Philippine Institute of Volcanology and Seismology (PHIVOLCS).[1]

Before Mount Pinatubo erupted in 1991 in the second-largest eruption of the 20th century, it was known as a "quiet" mountain. The 1991 eruption killed 350 people, left 200,000 homeless, and lowered the global temperature by 1.5°C. But warnings by PHIVOLCS before the eruption led to the evacuation of 200,000 people. This event helped demonstrate that close volcano monitoring, supported by public information campaigns and timely evacuation, could save thousands of lives.

Mount Mayon is no "quiet" mountain; it has erupted close to 50 times in the past 500 years. The volcano is geographically shared by eight cities and municipalities, whose residents have experienced "evacuation fatigue." To discourage evacuated residents from leaving shelters and returning to their farms, authorities often interrupt power and water supply within the danger zone. Authorities also struggle with "disaster tourists," who tend to ignore government warnings and venture into the danger perimeter.

[1] PHIVOLCS is a service institute of the Department of Science and Technology mandated to mitigate disasters that arise from volcanic eruptions, earthquakes, tsunami, and other related geotectonic phenomena.



2018 Mayon Volcano Lahar Hazard Map. *Source:* Philippine Institute of Volcanology and Seismology.

While the 1991 Pinatubo eruption highlighted the need for heightened vigilance and better knowledge of all volcanoes, including dormant ones, the Mayon volcano showed that zones where volcanic explosions are common tend to be more prepared than others (despite enforcement issues).

To ensure that risk communication is effective and accurate, experts need to make sure that decision makers can understand the situation at any time and are ready to take timely action. Alerts must be clear, solution-oriented, and directly transmitted by decision makers, especially in areas with wide access to social media. To minimize misinterpretation, local Philippine authorities do not use probability-based terminology when issuing volcano alerts, and they tailor the alert to the specific volcano that is threatening to erupt—that is, alerts take into account the characteristics of the volcano as well as the local characteristics of the area at risk (topography, density of settlement, proximity to other hazards such as landslides, etc.). For example, figure 1 shows alerts for Mayon volcano.

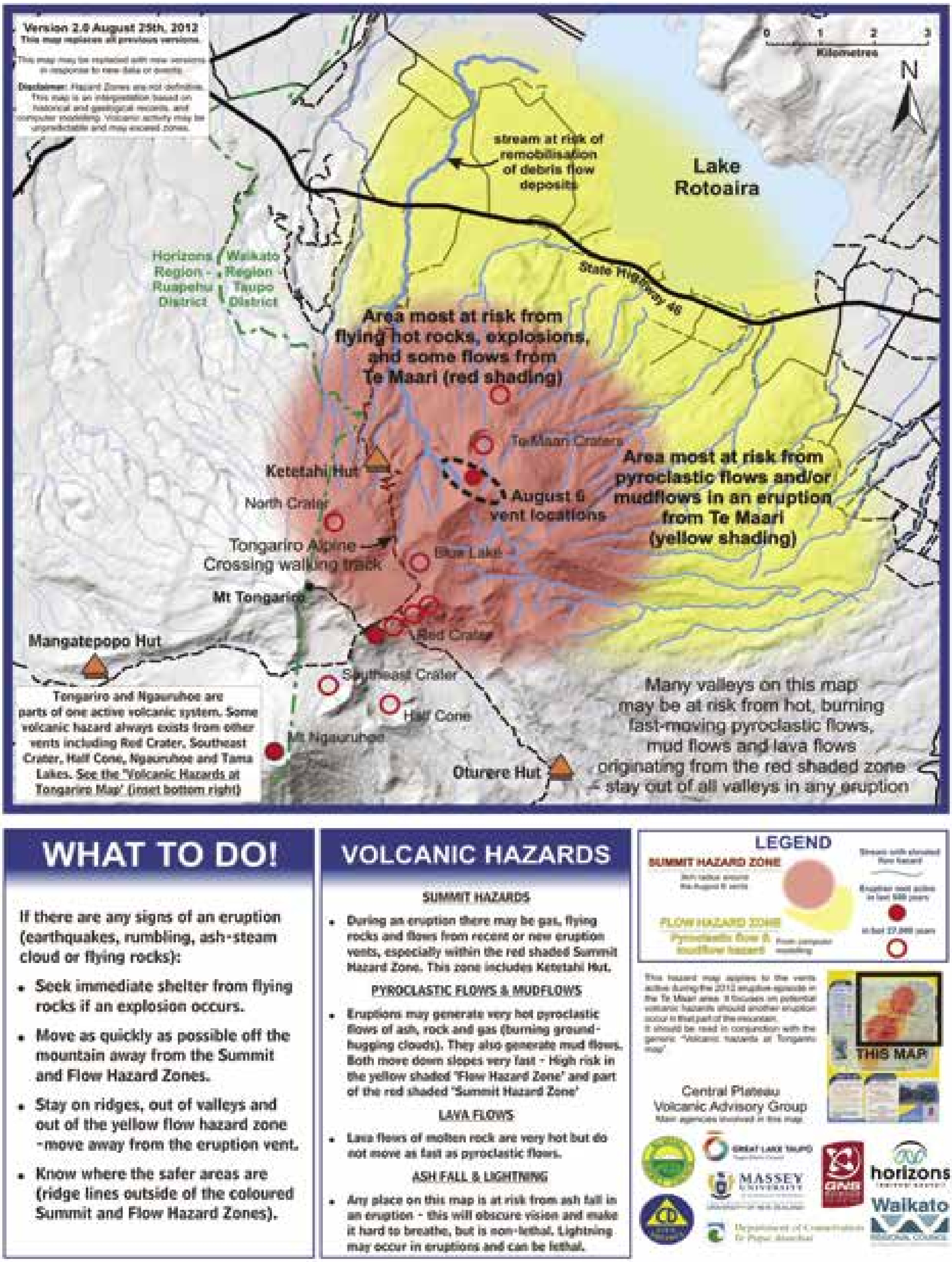
New Zealand: Local Knowledge and Scientific Tools to Monitor Tongariro Volcano

New Zealand needs to be prepared for a range of volcanic eruption styles in any of its 12 active volcanic areas. Its warning system incorporates possible human behaviors so the public can take appropriate and timely action (figure 2). Two complicating factors in New Zealand are that many volcanoes are located in natural parks with specific land use planning restrictions, and that indigenous communities often have their own perception and understanding of volcanic phenomena. A recurring challenge for local authorities has been to communicate risk in a way that is unambiguous and inclusive—that is, useful and usable, as well as culturally sensitive to different understandings of hazard and risk.

To address this challenge, New Zealand's GNS Science[2] seeks to

[2] GNS Science performs analyses that provide the information needed for planning to help minimize the impact of future volcanic eruptions.

Figure 2. Hazard map for the Te Maari crater, part of New Zealand's Tongariro volcano, with information on "What to Do."



Source: GNS Science, "Te Maari Eruption Phenomena Map," https://www.gns.cri.nz/Home/Learning/Science-Topics/Volcanoes/New-Zealand-Volcanoes/Tongariro/Te-Maari-eruption-phenomena-map.

New Zealand Volcanic Alert Level System

	Volcanic Alert Level	Volcanic Activity	Most Likely Hazards
Eruption	5	Major volcanic eruption	Eruption hazards on and beyond volcano*
	4	Moderate volcanic eruption	Eruption hazards on and near volcano*
	3	Minor volcanic eruption	Eruption hazards near vent*
Unrest	2	Moderate to heightened volcanic unrest	Volcanic unrest hazards, potential for eruption hazards
	1	Minor volcanic unrest	Volcanic unrest hazards
	0	No volcanic unrest	Volcanic environment hazards

An eruption may occur at any level, and levels may not move in sequence as activity can change rapidly.

Eruption hazards depend on the volcano and eruption style, and may include explosions, ballistics (flying rocks), pyroclastic density currents (fast moving hot ash clouds), lava flows, lava domes, landslides, ash, volcanic gases, lightning, lahars (mudflows), tsunami, and/or earthquakes.

Volcanic unrest hazards occur on and near the volcano, and may include steam eruptions, volcanic gases, earthquakes, landslides, uplift, subsidence, changes to hot springs, and/or lahars (mudflows).

Volcanic environment hazards may include hydrothermal activity, earthquakes, landslides, volcanic gases, and/or lahars (mudflows).

***Ash, lava flow, and lahar (mudflow) hazards may impact areas distant from the volcano.**

This system applies to all of New Zealand's volcanoes. The Volcanic Alert Level is set by GNS Science, based on the level of volcanic activity. For more information, see geonet.org.nz/volcano for alert levels and current volcanic activity, gns.cri.nz/volcano for volcanic hazards, and getthru.govt.nz for what to do before, during and after volcanic activity. Version 3.0, 2014.

Source: GNS Science

blend traditional knowledge with scientific expertise to reduce the social vulnerability of local indigenous communities living in areas prone to volcanic eruptions. In 2012, for example, two small eruptions took place on the northern flank of the Tongariro volcano. For this event, volcano risk communication was effective and sustained: the sociocultural needs of communities living near volcanoes—on what Maori culture often considers sacred land—were incorporated in monitoring efforts, contingency planning, and related preparedness measures (prior to the eruption). The result was not only constructive community involvement and optimal response levels, but also increased awareness of volcanic activities by local indigenous communities. Over time, this approach also increases the awareness of scientists and decision makers about how local indigenous communities understand and relate to volcanoes.

Colombia: Lessons from the 1985 Nevado del Ruiz Eruption

A relatively small eruption of Nevado del Ruiz volcano, located in Colombia's Central Cordillera, took place on November 13, 1985. The resulting lahars (volcanic mud and debris flows) made this event the second-deadliest volcanic disaster of the 20th century. The lahars descended through steep, narrow river canyons, reaching speeds of up to 45 kph. Lahar devastated the city of Armero, killing between 20,000 and 24,000. Another lahar flow descended the western slope of the volcano through the narrow canyon of the Chinchina River, killing as many as 1,800 people near the town of Chinchina. The loss of life was exacerbated by the lack of an accurate time frame for the eruption and the unwillingness of local authorities to take costly preventative measures without clear signs of imminent danger.

Challenges

Ineffective and inadequate communication turns extreme hazard events into calamities. Too often in the past, at-risk communities have not been sufficiently warned of impending threats or imminent danger by the scientists responsible for monitoring a restless volcano, for several reasons:

- *Technical challenges in predicting eruptions.* The rise of magma or gases from the volcano's depths to the surface is difficult to predict with certainty. The signals from earthquakes or ground deformation changes that imply that an eruption often occur and then subside, without an eruption taking place. Scientists are gaining access to ever greater volumes

Nevado del Ruiz volcano, with glacier covering summit and upper flanks.
Source: NASA Earth Observatory, "Nevado del Ruiz Volcano, Colombia," https://earthobservatory.nasa.gov/images/43859.

of data, but interpreting and communicating data is difficult. The public should be educated to understand that technical information is inherently uncertain.

- *Practical challenges in cooperating to communicate risk.* More study is needed to understand how institutional organization and the flow of information between different actors influence response to a crisis. Evidence suggests that good communication between decision makers enables them to gauge the volcano's behavior and develop forecasts that are relevant to local communities.
- *Lack of trust in predictions.* Many volcano scientists work in observatories that are rooted in communities and have a strong relationship with local government officials and the public. For them, the ability to engage with an anxious and perhaps skeptical or distrustful public is a key skill. Trust is an even greater issue when "remote" volcanologists are involved in active volcanic crises through social media, often without the knowledge of local scientists. The rise of social media as a communication channel offers considerable benefits and opportunities, but scientists should also be aware of potential threats and conflicts associated with its use.

Recommendations and Conclusions

Two recommendations are offered here:

First, don't forget volcanoes! Because they are comparatively infrequent, volcanic eruptions may be the "forgotten hazard." But volcanoes can have a devastating impact. About 250,000 people have died in the past 200 years as a direct consequence of volcanic eruptions, almost 26,000 of them in the past two decades (mostly in low- and middle-income countries). Today, about 500 million are directly subject to volcanic risk. In countries prone to volcanic eruptions, decision makers should routinely monitor these risks and incorporate these into broader disaster resilience measures.

Second, consider risk communication a two-way street. It is as important to genuinely listen to communities as it is to communicate to them. This receptiveness allows risk managers to learn what channels work best for creating awareness ahead of eruptions and for communicating during a crisis. Moreover, building communities' trust requires that communication be ongoing—occurring before and after as well as during an event. Communities must be made aware of the challenges of predicting eruptions well before the next crisis occurs.

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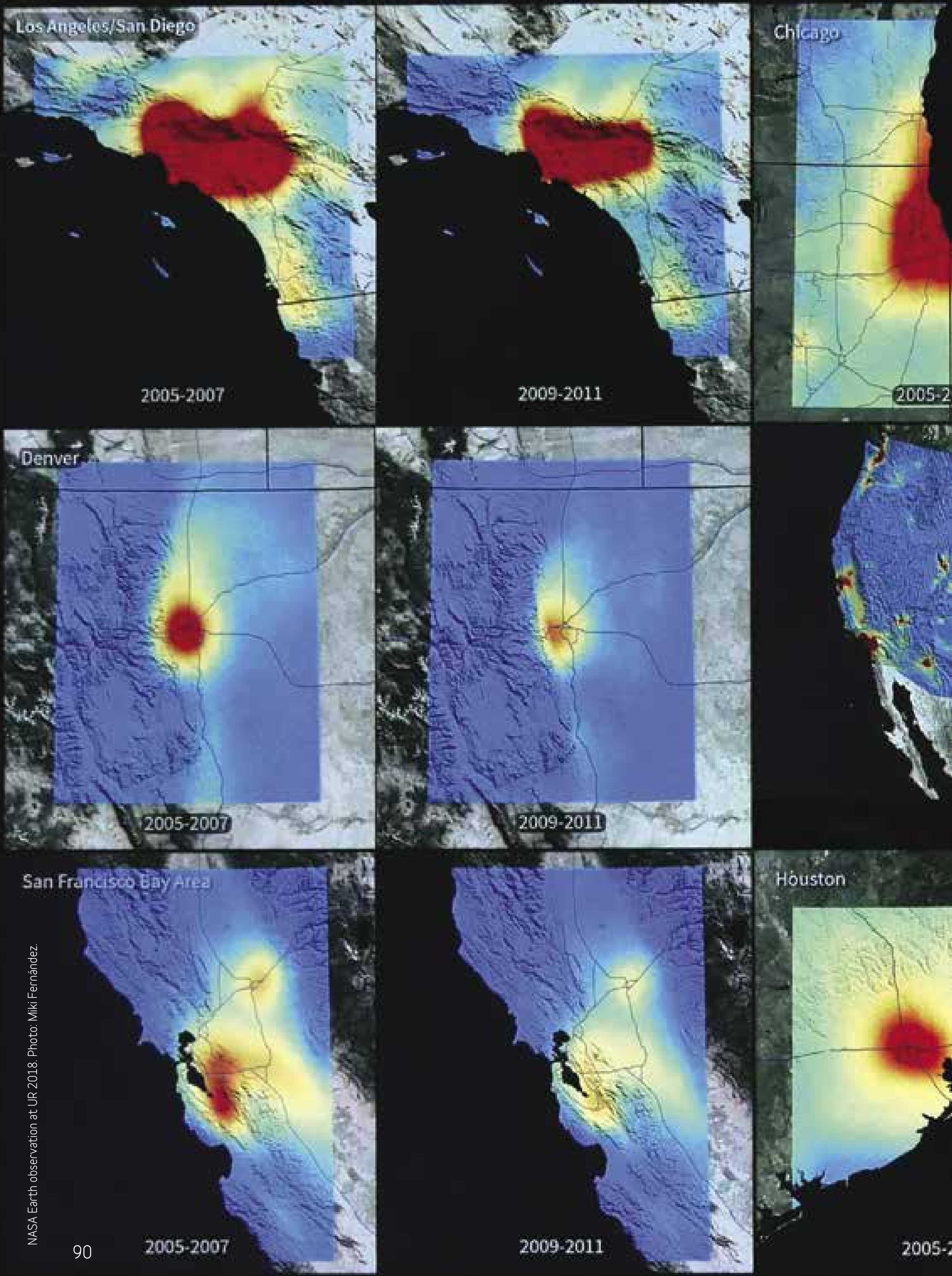
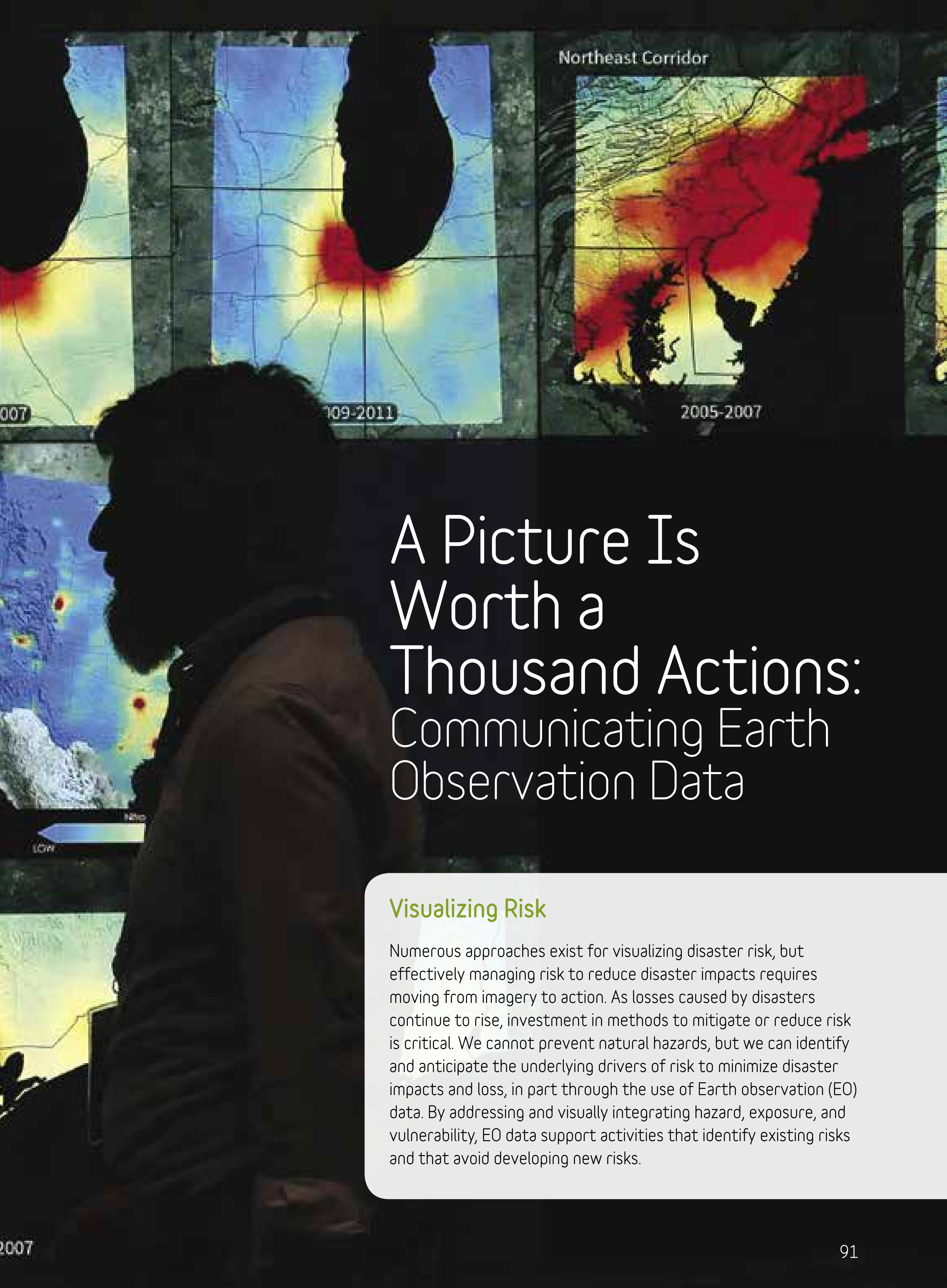
About 250,000 people have died in the past 200 years as a direct consequence of volcanic eruptions, almost 26,000 of them in the past two decades (mostly in low- and middle-income countries).



NASA Earth observation at UR 2018. Photo: Miki Fernández.

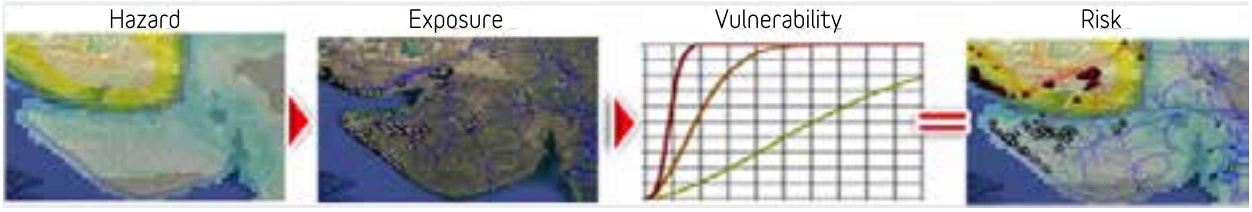


A Picture Is Worth a Thousand Actions: Communicating Earth Observation Data

Visualizing Risk

Numerous approaches exist for visualizing disaster risk, but effectively managing risk to reduce disaster impacts requires moving from imagery to action. As losses caused by disasters continue to rise, investment in methods to mitigate or reduce risk is critical. We cannot prevent natural hazards, but we can identify and anticipate the underlying drivers of risk to minimize disaster impacts and loss, in part through the use of Earth observation (EO) data. By addressing and visually integrating hazard, exposure, and vulnerability, EO data support activities that identify existing risks and that avoid developing new risks.

Data on hazard, exposure, and vulnerability are required for risk assessment.



EO data are a resource for quantifying community risk and visualizing the interconnectedness of populations, key infrastructure, and climate-related processes. Through high-resolution optical imagery and active sensors, remote sensing technologies enable disaster risk managers to quantify pre-disaster vulnerabilities as well as post-disaster damage. Remote sensing is also used to monitor recovery and reconstruction after significant disasters, as well as to monitor climate on an ongoing basis (see box 1). More recently, it has been used to develop exposure information for urban infrastructure.

Despite the benefits offered by EO data, the use of these important data sets remains limited. This disconnect often occurs when imagery providers, translators, and users fail to communicate, leading to the use of data and data products that are not relevant for the situation. In addition, EO data products and visualizations do not automatically translate to specific decisions but instead must be interpreted; beneficiaries and end users of data must therefore be trained in integrating data products into decision frameworks and must understand the limitations of these products.

When Dialogue Doesn't Effectively Communicate Risk

Even where open dialogue between data providers, data translators, and end users exists, a number of challenges remain in using EO data products to inform risk reduction. These challenges include a preponderance of data as well as various complexities—in timing of data use and scales of decision making, and in the social elements that affect communication.

- *Multiple types of data.* The growing demand for EO data, combined with innovations by private sector producers, has created an overabundance of data products. Where multiple visualizations of a particular disaster or risk type exist, it can be daunting to determine which data to use and which actions to take based on the data. These situations can place additional strain on response agencies' already limited capacity to process, manage, and effectively use data products.
- *Complexities in timing and scale.* End users often rely on assumptions regarding data products and visualizations and tend not to understand or seek information about the timing and scale of data being used. They may believe, for example, that high-resolution data are essential for every scale, and that data products and visualizations can be produced rapidly and with the most recent data (e.g., in real time).
- *Inadequate communication.* Dialogue among data providers, translators, and end users is vital for communicating risk—if it achieves certain ends. Dialogue should identify the end users' data literacy, determine the types of data they need, ensure that the messaging delivered will be clear and understandable, and clarify whether authoritative decisions can be based upon it. Furthermore, understanding the overall decision-making framework of the end user can reveal times when the integration of Earth observation data may be most useful and have the greatest impact.


Gayo village, Ethiopia. Farmers collecting rain water. Photo: Martchan.

Box 1. EO in Climate Information Services

Climate Information Services (CIS) are a critical resource for smallholder farmers of rain-fed crops, particularly those on the frontlines of climate change in Sub-Saharan Africa. Timely, accurate information—derived in part from EO data—helps farmers make informed decisions about what to plant, when to harvest, and how to safeguard against crop diseases.

However, CIS programs often fall short of their potential effectiveness because providers make unfounded assumptions about end users, their needs, and the purposes for which they use climate information. Providers' failure to engage with or receive feedback from users hampers development of products that are appropriate for their context as well as useful and accessible for their intended audience.

Under the USAID-funded Climate Information Services Research Initiative (CISRI), a Mercy Corps–led consortium is working to close this gap between producers and users of risk information. Focused on CIS in Sub-Saharan Africa, CISRI has developed and piloted a participatory systems-mapping approach that engages users to ensure products are context-appropriate, useful, understood, and accessible. Through a series of tiered workshops from the village to the national levels, CISRI supported smallholder farmers in three regions of Senegal and Niger. The workshops helped define farmers' CIS needs; facilitated their dialogue with local, regional, and national authorities; and identified opportunities for improving the CIS system. In the process, they brought stakeholders from across the communication chain together to discuss the challenges of communicating risk information, including constraints imposed by language, timing, and gender-related cultural norms.

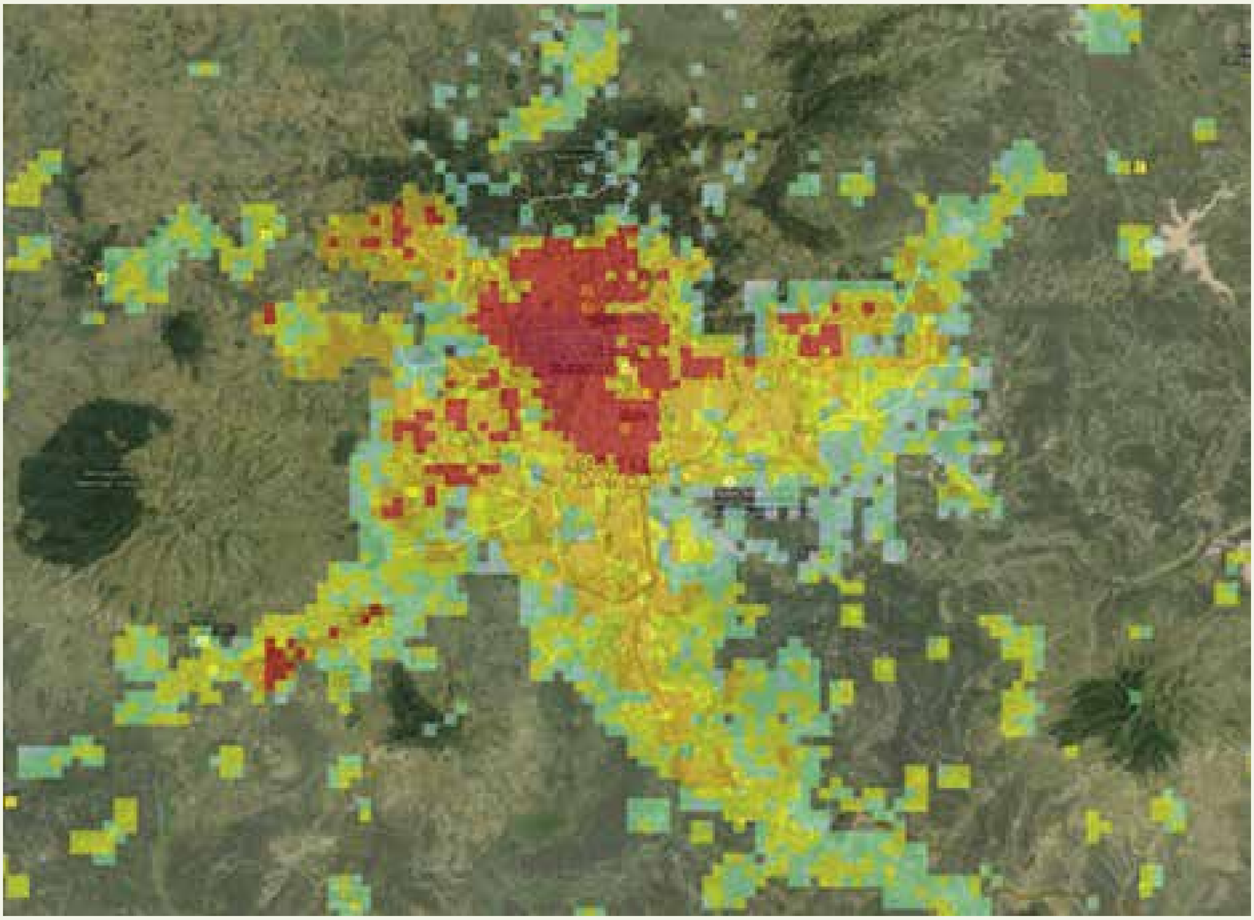
The value of this approach is already emerging. In the Tillabéry region in Niger, field agents from the Catholic Relief Services–led BRACED program (SUR1M) used ideas from the CISRI pilot to improve the provision of CIS, and in particular to address blockage points for farmers in accessing CIS. The team is designing a method for CIS diffusion, in which short messages containing forecast information will be shared with the local radio stations and the village-level early warning groups. Efforts to have local radio stations transmit the messages free of charge and in the local language are under way, ensuring their accessibility to a greater number of farmer-users.

More information is available at
Climate Links, "Learning Agenda for Climate Services in Sub-Saharan Africa," https://www.climatelinks.org/projects/learningagendaonclimateservices.

Box 2. Generating Population, Economic, and Physical Exposure Data Sets Using EO Imagery

Applying a methodology developed under NASA ROSES grant NNX14AQ13G, ImageCat and key partner CIESIN (Center for International Earth Science Information Network) generated data sets that helped measure population exposure as well as economic and physical exposure in eight Sub-Saharan African nations (see figure 1 for a sample). This information is being used to estimate expected socioeconomic losses from a number of natural phenomena under the Global Facility for Disaster Reduction and Recovery/World Bank Disaster Risk Financing and Insurance Program. According to Stuart Fraser of the World Bank, "These data sets provide vital new information enabling risk assessment to be conducted in several data-poor countries, and they form a basis from which to improve the collection of exposure data there."

Figure 1. EO imagery of Addis Abba used to determine exposure of physical assets.



Addis Ababa, Ethiopia Buildings per 15 arc-second grid	0	1-5	5-25	25-100	100-250	250-500	500-1000	1000-1635

Source: ImageCat Inc.

Moving from Imagery to Action

Overcoming the multiple challenges involved in using EO data is possible; see box 2 for a good example of EO data that are useful and actionable. To address the most common challenges, several steps are important:

First, a *dialogue must be established among stakeholders,* including (1) providers of imagery (e.g., NASA and commercial satellite companies); (2) the translators who produce pre- and post-disaster products (e.g., risk modeling companies, research organizations, and universities); and (3) the users of this information (e.g., humanitarian response and emergency management agencies). This initial step offers end users the ability to identify the shocks and stresses within their community, so that imagery providers develop products that accurately reflect risk. It also enables translators of the imagery to place the system-specific data in a context that can empower decision frameworks for disaster risk reduction.

Additionally, we must look to the development of the visualizations and tools to ensure that the *data are actionable by a number of end users—without duplicating or overproducing tools*. Moving the decision points out of the disaster response setting to a period before a disaster occurs allows for better integration of complex data sets. It also facilitates discussions of the different tools for reducing risk and the different roles they can play.

Finally, data producers and end users need to *establish networks, technical expertise, and trust before a disaster happens*. Risk changes rapidly; learning how to develop decision support systems quickly is therefore important for reducing loss of life, livelihoods, and property. Embedding risk reduction and risk communication into broader strategies that match the nature of risk—and the needs of the audience making use of the visualizations—can support effective decision making.

As we are better able to coordinate data needs and improve integrated risk-informed approaches, the ability to translate a single picture into effective action becomes more believable—and more likely.

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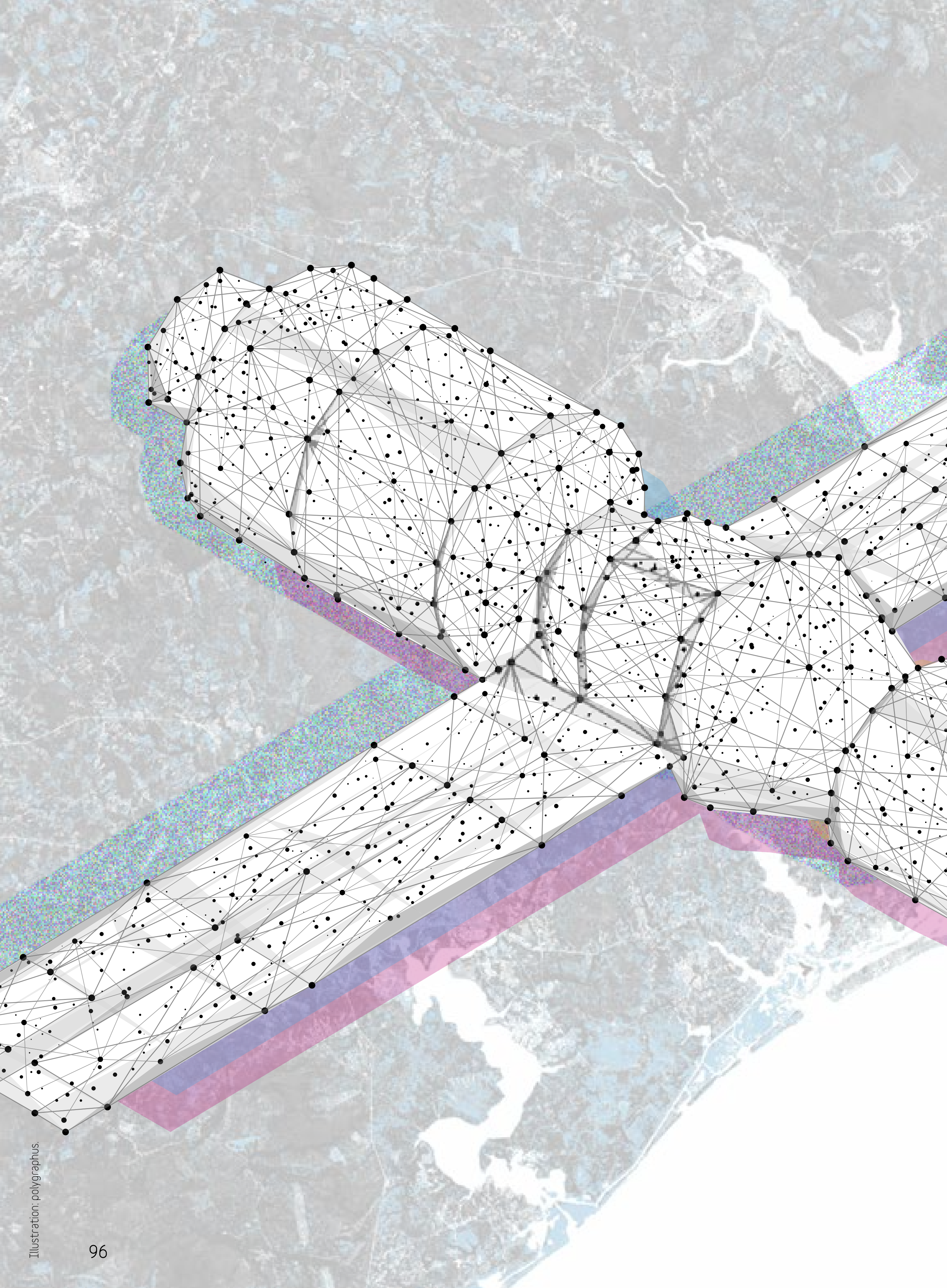
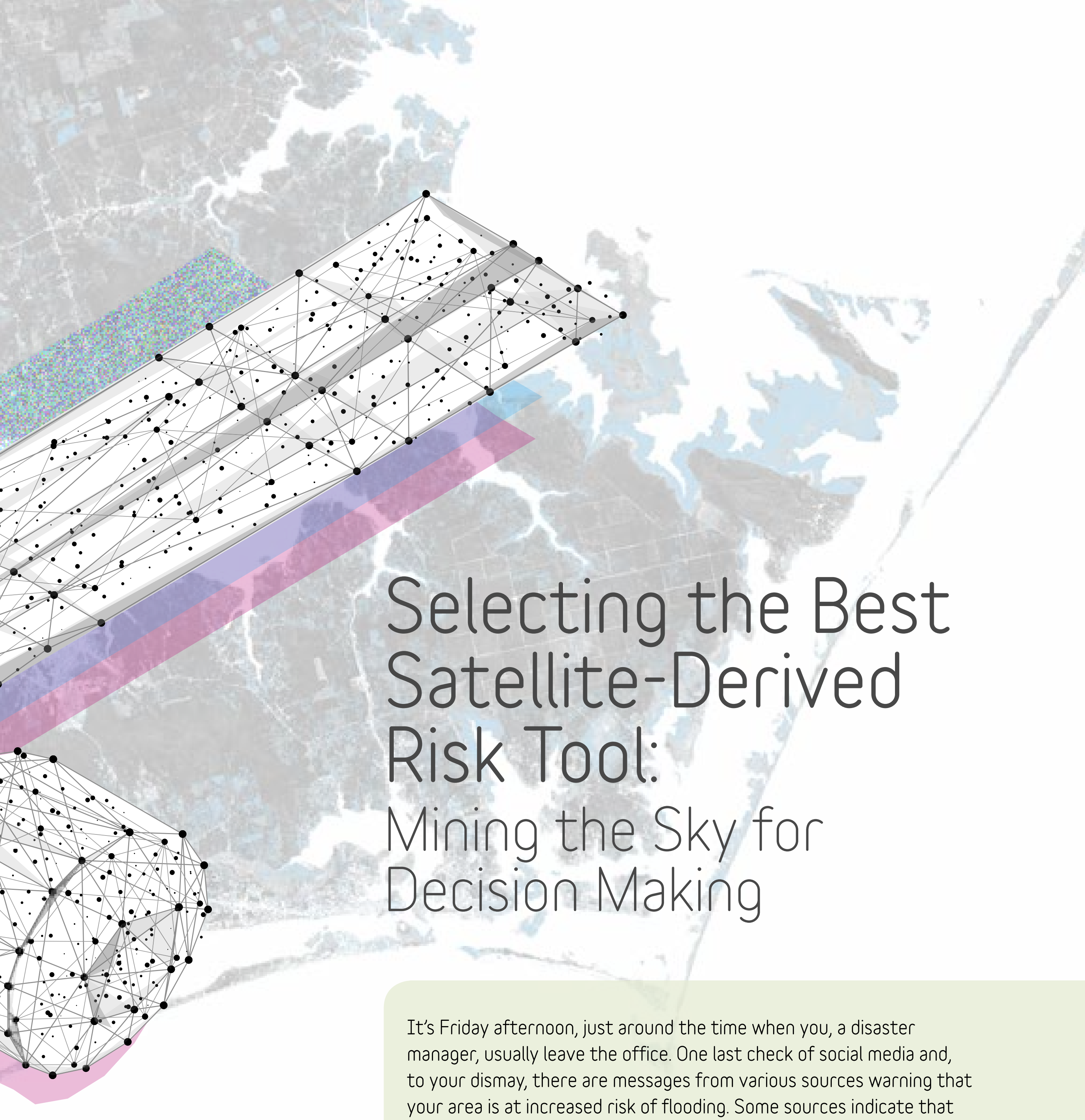


Illustration: polygraphus.



Selecting the Best Satellite-Derived Risk Tool:

Mining the Sky for Decision Making

It's Friday afternoon, just around the time when you, a disaster manager, usually leave the office. One last check of social media and, to your dismay, there are messages from various sources warning that your area is at increased risk of flooding. Some sources indicate that flooding will definitely occur at scales never before experienced. Others are more cautious, highlighting the risk for moderate floods though also suggesting that flash flooding could happen in areas that have not experienced it before.

You need to take action—what do you do? What risk products can you access? Which ones do you *really* trust enough to *use*?

The Gap between Availability and Use of Risk Products

There is currently a gap between the availability of hazard risk tools, such as forecasts, interfaces, and maps, and use of those tools. But what does it mean to "use" a tool—that is, what makes a tool useful? The usefulness of risk tools to specific decision makers should not be considered binary; instead, the perception of usefulness exists along a spectrum, ranging from "I perceive this risk product to be useless" to "I can justify changing a decision based on the output of this product." Viewed through the lens of opportunity cost, one tool may be deemed an inefficient use of costly, scarce time and human resources, while another can be seen to have direct potential economic and social benefits.

Risk tool developers and members of the disaster risk management community came together at a session of UR2018 to better understand the reasons for the gap between availability and use of tools, and to explore ways to bridge it. The presentations at this session made clear that this gap is all too real. The physical science that informs the research and development of risk tools continues to advance, and the availability of tools on the Internet increases; but the use of risk tools, especially those on the "very useful" side of the spectrum, is increasing at a much slower rate. One primary barrier to closing the gap is poor communication between risk tool developers and potential tool users. Neither group understands the other's capacities, motivations, and intentions, in part because users are not clearly communicating what types of hazard risk tools they find useful, and developers are not communicating what the science is capable of.

From the interactive MapSlam subsession, the need for a "translator" emerged as a critical priority. This person would first define the gaps between availability and use and then design pathways to foster the exchange of ideas between developers and users. But the role of translator needs to be well defined. As one participant said, "We all agree that a translator role is important, but there needs to be a definition of what it consists of—the translator's roles and responsibilities—in order to legitimize the position."

Disaster managers needed to make a decision about where to prioritize first response after news of large-scale flood impacts was reported, but they received multiple maps that the senders did not link to any specific action.

The Example of Satellites

In the effort to develop useful risk products, the example of satellites is instructive. Presenters at this session shared a range of cases across different sectors in which remotely sensed satellite data—both in the form of optical imagery and in risk products derived from raw data—was critical for making specific decisions. Ahmadul Hassan of the Red Cross Red Crescent Climate Centre presented a case study in which satellites served as key elements of forecast-based financing, specifically by providing snapshots of tropical cyclone propagation toward (or away) from populated areas on the Bangladesh coastline. Gabriella Nobre of the Institute for Environmental Studies (IVM) in Amsterdam conveyed the importance of integrating satellite data on rainfall anomalies with socioeconomic data to better understand drought risk. Using Hurricane Maria as a case study, Miguel Román of the NASA Goddard Space Flight Center explained the use of nighttime light detection as a proxy for impact driven by deviations in "normal" nighttime light conditions. Finally, the International Research Institute for Climate and Society (IRI) team explained how satellites were useful for understanding the risk of flash floods and landslides in the Rohingya refugee camps.

Specific Maps for Specific Decisions

The example of the Rohingya refugee camp highlighted a further important point: even if satellite

Figure 1. Seven flood maps with validated spatial accuracy produced during the January 2015 Malawi floods. The shelter locations are based on Red Cross and UKAID information. Image credit: NASA DEVELOP Malawi Disasters Team, International Research Institute for Climate and Society, spring 2015.

data are available and quality controlled from a geophysical perspective, this doesn't mean they will be either used or trusted. A study of the 2015 floods in Malawi showed the same thing: disaster managers needed to make a decision about where to prioritize first response after news of large-scale flood impacts was reported, but they received multiple maps that the senders did not link to any specific action. Yes, these maps may have been useful for generally conveying the message "floods have happened," but they failed to convey what type of floods were shown and hence what type of response was warranted. Figure 1 shows the satellite-derived maps indicating where flooding occurred in January 2015. Note the differences in the extent of flood signal.

The Importance of Context

In her summary of the session, Lace Padilla said that understanding human cognition is necessary for accurately predicting decision making about risk. This is a point for developers of risk products to keep in mind. More specifically, developers might be guided by the following questions as they determine what risk products to develop for decision makers.

- For whom is the tool appropriate? People's training, experiences, and risk tolerance influence how they see and understand satellite data. It is essential to tailor the information presented so that the specific audience understands it accurately.
- For what decision is the tool appropriate? People require different information for different decisions. If too much information or irrelevant information is shown, the audience will likely be distracted, and they will make poor decisions because they are not focusing on the information they need.
- When is the tool appropriate? By default, we make fast snap decisions, particularly in high-risk situations. However, we can make more careful and considered decisions given sufficient time. Working with decision makers in advance of a hazard event to help them understand and practice with the product will promote good habits that can be employed when disaster strikes.

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People require different information for different decisions. If too much information or irrelevant information is shown, the audience will likely be distracted, and they will make poor decisions because they are not focusing on the information they need.

"World's best event for networking and inspiration on risk matters."

Communicating Risk:

Approaches for Parametric Insurance

The severity and increasing frequency of disasters over the past 10 years have prompted countries in Latin America, the Caribbean, and the Pacific to pursue disaster risk financing (DRF) strategies as part of a comprehensive approach to disaster risk management. DRF strategies reduce the economic and fiscal impact of disasters, while also aiming to be cost-effective. These strategies should ideally be developed before a disaster strikes, be integrated into core public finance systems, and combine a variety of risk retention and transfer instruments within a disaster risk management legal framework. One particularly effective risk transfer instrument for sovereign governments is parametric insurance.

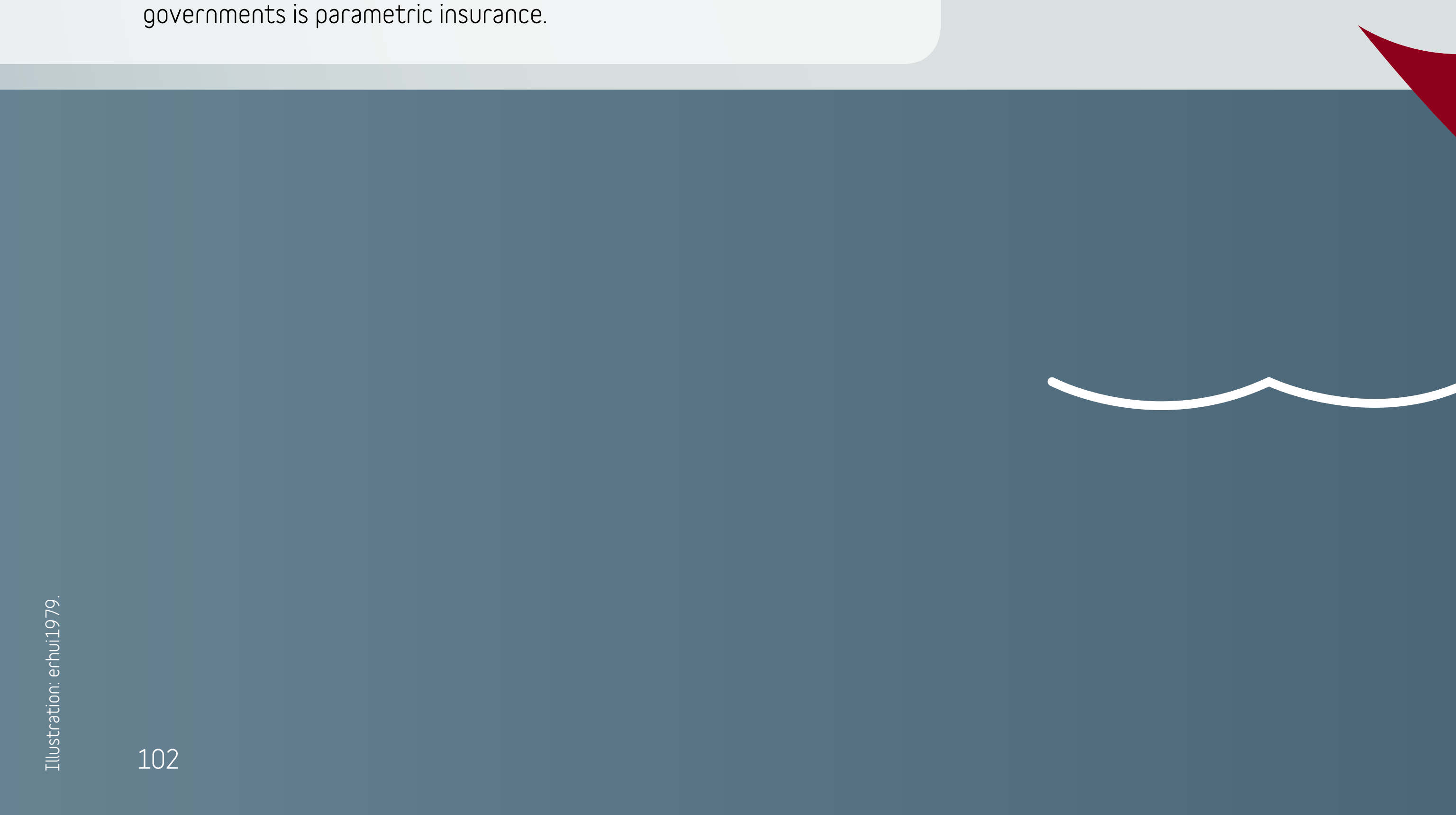

Illustration: erhui1979.

"A disaster is a terrible thing to waste."

—Isaac Anthony, Chief Executive Officer, Caribbean Catastrophe Risk Insurance Facility (CCRIF-SPC)

Parametric insurance mechanisms, which could include multi-country risk pools and catastrophe bonds, limit the financial impact of devastating events such as earthquakes, tropical cyclones, and droughts by offering rapid payouts when losses occur and coverage is activated. Following Hurricanes Irma and Maria in 2017, the Caribbean Catastrophe Risk Insurance Facility (CCRIF-SPC), essentially a parametric risk insurance pool, paid out over US$50 million to member countries just days after the events.

But parametric insurance products are complex instruments. How should their features and benefits be communicated to politicians, citizens, and other stakeholders? This UR2018 session addressed this question by looking at the experiences of Mexico, Tonga, the Philippines, and regional risk pools in the Caribbean and the Pacific.

Background and Concepts

Parametric insurance products make payments based on certain parameters—the intensity of an event (for example, wind speed, earthquake magnitude, volume of rainfall) and/or the amount of loss calculated in a pre-agreed model. Unlike traditional indemnity settlements, which require an on-the-ground assessment of individual losses, parametric insurance relies on a triggering mechanism using a predefined methodology, one based on variables that are exogenous to both the individual policyholder and the insurer. Some differences between the two types of insurance are summarized in table 1.

Parametric insurance mechanisms are useful because they limit the financial impact of devastating events by offering rapid disbursements when a triggering event occurs and a policy is activated. Parametric insurance coverage can be provided through an insurance or reinsurance contract, as well as through the issuance of a catastrophe bond.

Using parametric insurance does entail certain risks. Given that disbursements depend on triggers, countries or policyholders must fully understand the conditions that determine a trigger, and verify that the relationship between these conditions and the potential financial or economic loss is accurately established. The uncertainty between modeled risk and the actual risk, along with the consequent difference in payment, is often referred to as "basis risk" and is an important factor to consider when designing parametric structures.

Case Studies

Session presenters shared the reasons for adopting parametric insurance mechanisms and explained how their countries or regions have integrated these mechanisms into a comprehensive DRF strategy.

CCRIF

In 2004, Hurricane Ivan devastated a number of islands in the Caribbean, causing damages and losses to the tune of US$6 billion. In Grenada and the Cayman Islands, losses amounted to 200 percent of GDP. This disastrous event served as a wake-up call for the region and galvanized governments to take action.

With technical assistance from the World Bank and financial support from donors, a parametric insurance pool, CCRIF, was developed. This DRF tool was selected from among others because countries felt in urgent need of a rapid post-disaster disbursement mechanism. After

Table 1. Traditional vs. Parametric Insurance

	Traditional insurance policy	Parametric insurance policy
What is a loss?	An appraisal of replacement/ reconstruction costs after a damage (indemnity)	An estimation of damage as captured by a model, index, or other set of parameters
How is payment determined?	Ex post: Payment is based on appraised value minus deductible and co-insurance	Ex ante: A triggering event is verified in the model
How fast is payment usually made?	Appraisal times (availability and process) determine payment	Payment usually occurs in days once the triggering event is verified

past disasters, they had struggled to find resources to meet immediate recovery needs: funds from donors generally take a long time to coordinate and manifest, and humanitarian support tends to be relatively small compared to needs on the ground.

Mexico

Parametric insurance coverage through catastrophe bonds forms a critical layer in Mexico's overall DRF framework, administered under FONDEN, Mexico's Natural Disaster Fund:

- FONDEN includes a first layer by providing financial resources for rapid post-disaster emergency response, recovery, and rehabilitation efforts. FONDEN receives budget resources annually from the government.
- Indemnity or traditional insurance, the second layer, supports reconstruction.
- Parametric catastrophe bonds, the third layer, are intended to fill the financial gap between emergency response and reconstruction.

Following Hurricane Patricia in 2012, Mexico received its first payment from the triggering of a catastrophe bond (the amount was US$50 million). A powerful (M8.2) earthquake on September 8, 2017, triggered another catastrophe bond, prompting payment of US$150 million. Months later, in February 2018, Mexico successfully participated with the three other Pacific Alliance countries (Chile, Colombia, and Peru) in the joint catastrophe bond issued by the World Bank. This landmark US$1.36 billion transaction was possible in part due to Mexico's leadership, example, and ability to motivate the member countries to agree on the merits and terms of the joint risk transfer strategy. The transaction further validates the benefits of parametric insurance for disaster-prone countries.

Tonga and PCRAFI

The Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) provides Pacific Island Countries with disaster risk modeling and assessment tools. It also engages them in dialogue on integrated financial solutions that reduce their financial vulnerability to the impacts of disasters and climate change. The initiative, part of the broader agenda on disaster risk management and climate change adaptation in the Pacific region, helped to establish the Pacific Catastrophe Risk Insurance Company.

Tonga has worked with PCRAFI to address its extreme vulnerability to natural hazards, a function of its small size and exposed location in the Pacific Ocean. The government became interested in parametric products after having to cover frequent economic losses stemming from catastrophic events, and in 2013 it joined the PCRAFI insurance pilot. This step was part of a regional commitment made by the Pacific countries during the Finance and Economic Minister's Meeting that year. Tonga received US$1.3 million following Cyclone Ian in January 2014 and so became the first country in the Pacific to receive a payout under the insurance program. The payout received by Tonga from Cyclone Gita in February 2018 was the largest in the region at US$3.5 million.

The Philippines

Like Mexico, the Philippines has adopted a risk-layering approach that combines different instruments to protect against events of different frequencies and severities. For example, its parametric catastrophe risk insurance program provides cover against extreme events; for more common and less devastating events, it relies on the National and Local Disaster Risk Reduction and Management Funds or contingent credit lines.

As part of a new disaster risk insurance program, in July 2017 the Philippine Department of Finance placed a pilot catastrophe risk transaction with annual parametric coverage of US$206 million. The program covers the national government against losses from earthquakes and severe typhoons, and covers 25 provincial governments against losses from severe typhoons.

Challenges

During the session, the audience raised questions about disaster risk financing and how best to communicate its impact. A couple of key questions and answers are presented below.

Q: With parametric insurance, how do you reconcile the size of payouts in relation to the total losses countries face?

A: Parametric insurance mechanisms are not designed to cover all damages or losses. Their purpose is to provide quick liquidity in the aftermath of a disaster. As in the case of Mexico, it is expected that other DRF tools will be used to complement parametric insurance mechanisms and minimize the financial burden on governments.

Q: In discussions with the public and stakeholders, how should governments communicate about parametric insurance?

A. Parametric insurance (and DRF tools in general) can be difficult to explain because of their technical nature. The most effective way to explain the tool is to emphasize its impact. Instead of simply indicating that a country received a payout, communicate how the funds were used—for example, to support immediate response efforts that improve conditions for disaster victims before other financial instruments have been mobilized.

Recommendations

The session generated a number of recommendations for enhancing the impact of DRF tools:

- Expand the hazards covered by parametric insurance to include floods and drought.
- Encourage collaboration around various risk insurance facilities and users (such as CCRIF, PCRAFI, Mexico, and other Pacific Alliance members) to further develop tools and foster innovation.
- Make insurance more affordable so that more countries can purchase policies.
- Determine how parametric insurance can be expanded to include individuals, livelihood protection programs, and specific sectors not targeted by traditional insurance.
- Given the influence of politicians and other key stakeholders on the sustainability of DRF products, develop communication strategies tailored to these groups.

Overall, the session fostered lots of discussion, which increased the audience's understanding of DRF strategies and their use. Along with the presentations and country examples, the discussions should pave the way for beneficial innovations to parametric insurance in the future.

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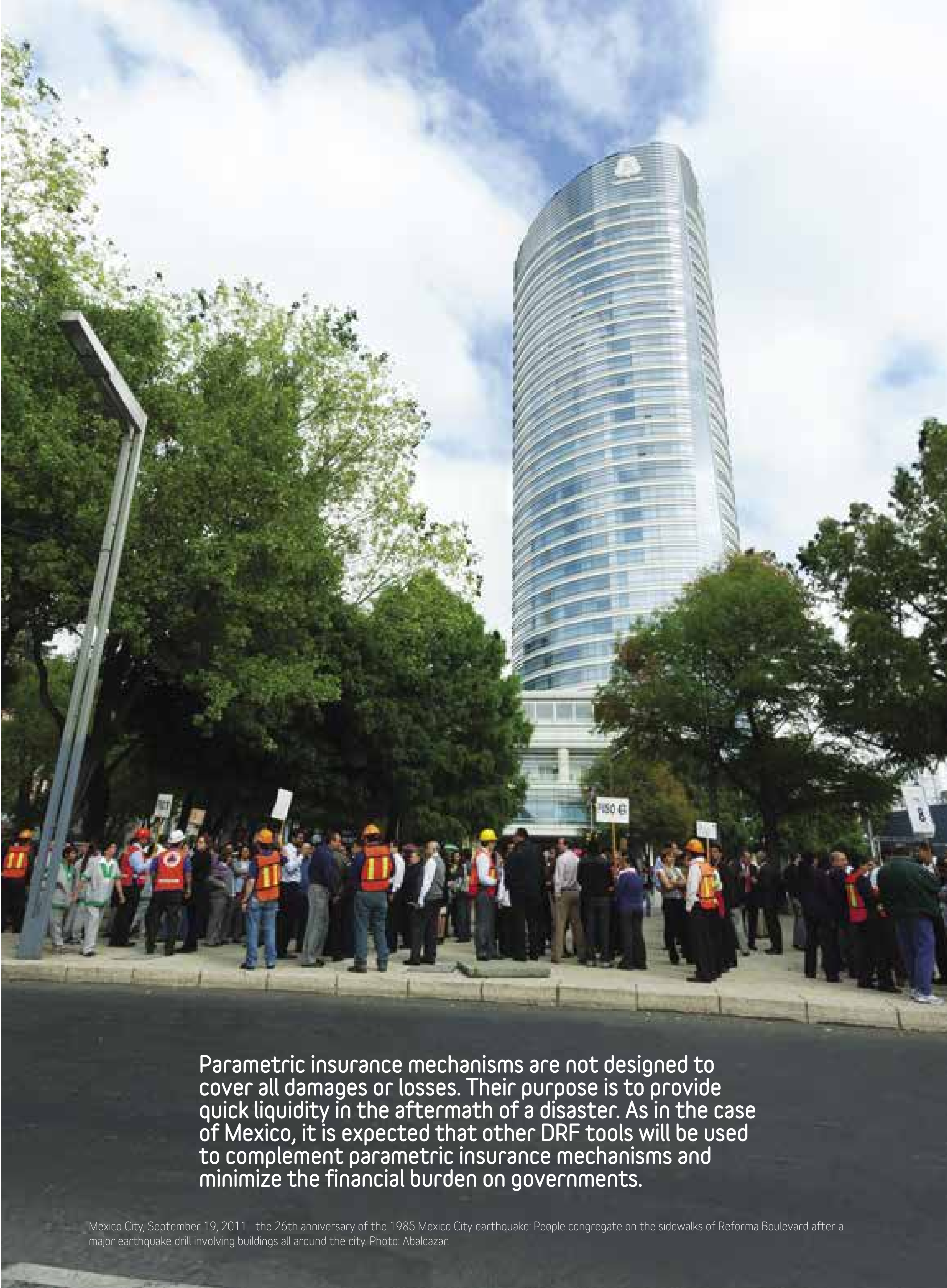

Parametric insurance mechanisms are not designed to cover all damages or losses. Their purpose is to provide quick liquidity in the aftermath of a disaster. As in the case of Mexico, it is expected that other DRF tools will be used to complement parametric insurance mechanisms and minimize the financial burden on governments.

Mexico City, September 19, 2011—the 26th anniversary of the 1985 Mexico City earthquake: People congregate on the sidewalks of Reforma Boulevard after a major earthquake drill involving buildings all around the city. Photo: Abalcazar.

Side Event

The Interdisciplinary Pressure Cooker Event on Risk Communication: Supporting the Next Generation of Risk Communication Professionals

Photo: Robert Šakić Trogrlić.

Many young researchers and professionals work in silos within their own disciplines and lack opportunities to think about how scientific information can be communicated to those who need it most. Improving risk communication will maximize the use of available scientific knowledge and encourage users to take more risk-informed decisions. New interdisciplinary training and capacity-building approaches are needed to develop applied tools and techniques for risk communication that integrate knowledge from multiple disciplines such as risk modeling, environmental and social science, media and communications, urban planning, information and communications technology, and community engagement.

What Did We Do?

The Water Youth Network (WYN) and Global Facility for Disaster Reduction and Recovery (GFDRR), with support from the Natural Environment Research Council (NERC), FM Global, and NASA, organized the Interdisciplinary Risk Communication Pressure Cooker event at UR2018. Thirty-five young professionals and researchers, representing 13 countries and a range of disciplines, came together at this event to address risk communication challenges in the Mexican municipalities of Iztapalapa in Mexico City and Dzilam de Bravo in Yucatán. The challenges were prepared collaboratively by the organizers, local-level stakeholders, Mexican-based researchers, and a team of mentors composed of different topic-specific specialists. The event aimed to build the capacity of these young professionals and researchers to work across disciplines and co-develop innovative risk communication solutions. Details on the design of the challenge and the winning teams' solutions can be found in the event evaluation report.[1]

What Were the Outcomes?

The event produced new insights into designing interdisciplinary solutions and enabling interdisciplinary teamwork. It allowed participants to jointly develop solutions and express ideas based on their discipline-specific expertise. The event helped participants step outside their comfort zone, although the time constraint kept some participants (e.g., environmental scientists and engineers) from contributing their ideas in depth. Even so,

What Participants Said

"We sometimes forgot to make use of these different backgrounds."
—Urban planner, Germany

[1] The final report is available on the WYN website at http://www.wateryouthnetwork.org/understanding-risk/.

participants were able to develop interdisciplinary solutions and propose risk communication outputs for real issues facing the study areas.

The event helped build a community of young professionals and researchers on risk communication who think differently about working with other disciplines. The participants exchanged experiences with their peers from different disciplines across the world. The community has now partly been absorbed into the Water Youth Network Disaster Risk Reduction team and will continue to engage with the Understanding Risk Community.

The event gave participants opportunities to apply their new skills in local contexts across the world. Participants gained new knowledge of the wide variety of risk communication mechanisms available, built interdisciplinary teamwork skills, and learned to make the target audience central to the process of designing a communication approach.

What Did We Learn for Future Events?

A number of lessons emerged from this event:

- Trust youth—and let them lead. This event was designed and implemented by a team of young professionals with support and guidance from experienced mentors. The youth organizations rose to the occasion to deliver innovative and creative content that inspired both peer-to-peer and intergenerational learning. Providing youthful participants and organizers with funding, trust, and space will ensure similar events in the future.
- Strengthen interdisciplinary participation. The event showed that some disciplines are more difficult to engage than others; there were comparatively few applications from creative disciplines (e.g., the arts, graphic design) and community engagement specialists.
- Provide context for real-life challenges. Real-life case studies were selected; case study specialists were available to guide teams; and a post-event field trip was arranged to one of the case study areas. Teams should be provided with as much local contextual information as possible to develop meaningful solutions.
- Time constraints affect outputs. The event was designed as an intense 24-hour pressure cooker. This created strong relationships between the participants, but did not allow for very detailed solutions.

> *"I will think a lot more about who my audience is, and how I can tailor my ideas (and my presentation of those ideas) to my specific audience and their own backgrounds, interests, and concerns."*
> **—Civil engineer, United States**

> *"One of the really valuable aspects of this event will be the network that has been created, which I have no doubt will be an incredibly useful resource to all of us in the future."*
> **—Environmental scientist, United Kingdom**

We want to end by saying a special thank you to NERC, FM Global, NASA, and others for funding youth participation at this event, and to all the support mentors, case study specialists, and volunteers who helped to make the event a success.

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Side Event

Lights! Camera! Risk-Informed Action!

Making and Using Videos for Effective Communication of Risks and Good Practices to Address Them (Storyboard)

Scene 1: Introduction; Shot 1: Objectives

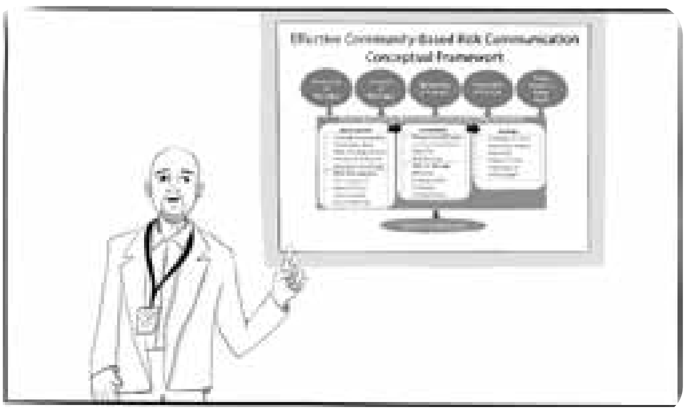
Illustrations: Andrea Fernandez

Dialogue (paraphrased): Video is a popular way to learn things today—so using video for risk communication makes sense. (Steven, event participant)

Action (summary): In this scene, participants were introduced to the workshop topic—using videos to communicate local-level risks and replicable approaches to address these risks—and to the workshop agenda, which included a presentation on effective use of video, group work, and a carousel activity.

FX (links): workshop slides = www.slideshare.net/BobAlexander13/ur2018-gptv-presentation15may18

Scene 2: Presentation; Shot 1: Theory Framework



Dialogue (paraphrased): Main considerations are roles of products, processes, key people/champions, and conditions (Anna Hicks, workshop co-facilitator)

Action (summary): Risk communication involves complementary products and dialogue processes that are accurate and relevant to/owned by local at-risk populations; it seeks to overcome motivations, intentions, and behaviors that constrain risk-managed decisions and actions.

FX (links): theoretical framework = rlrmc.barefootbob.net/wp-content/uploads/2018/03/risk8.png

Selected References and Resources

Alexander, Bob. 2015. "Effective Community-Based Risk Communication Conceptual Framework." Presentation at the International Conference of the Integrated Disaster Risk Management Society, New Delhi, October 28–30. http://rlrmc.barefootbob.net/wp-content/uploads/2018/03/risk8.png.

rlrmc.barefootbob.net. "Good Practices in Video: The Good Practices TV Song." 2018. http://rlrmc.barefootbob.net/wp-content/uploads/2018/08/GoodPracticesTV12Aug18.mp4?_=2.

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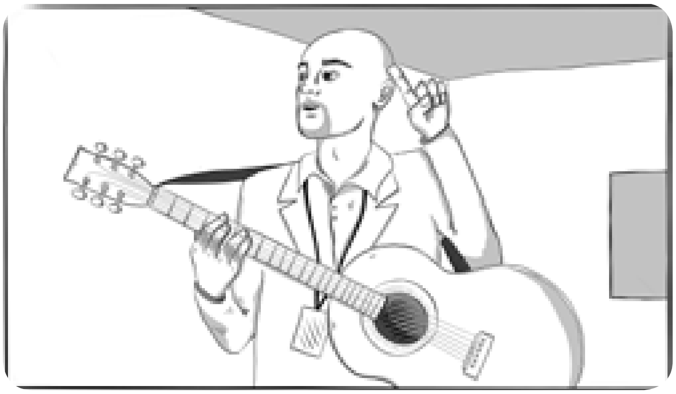
Scene 2: Presentation; Shot 2: Song/Rationale

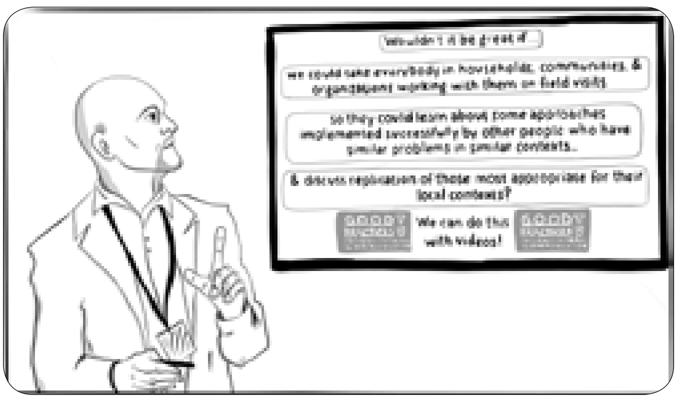


Dialogue (song lyrics excerpts): "To encourage dialogue in participatory communication / That helps inform decisions and actions that are taken . . . We want people to see good practices in videos."

Action (summary): An interactive original song summarized the rationale behind and key elements of using videos for effective risk communication, linking the theory to practical initiatives and technical and content-quality criteria.

FX (links): song lyrics video = rlrmc.barefootbob.net/wp-content/uploads/2018/08/GoodPracticesTV12Aug18.mp4?_=2

Scene 2: Presentation; Shot 3: Theory into Practice



Dialogue (paraphrased): Storing and categorizing good-quality videos in one place will help local decision makers access helpful information. (Fawad, event participant)

Action (summary):

- Good Practices TV is a new initiative for "virtual field visit" videos categorized by problem type.
- Examples showed how videos on this website address technical and content-quality criteria (e.g., how engagingly videos explain and show problem context, solution implementation, and results).

FX (links): Good Practices TV = www.goodpracticestv.com & https://rlrmc.barefootbob.net/wp-content/uploads/2018/08/GPTV-Promo15May18.mp4?_=3

Scene 3: Group Work; Shot 1: Discussion of Criteria

Dialogue (paraphrased): Information is buried in reports. Videos should show decision makers relevant practices from other places—and how to apply them in the local context. (Robert, event participant)

Action (summary):

- Based on the Good Practices TV video-scoring criteria, groups discussed more criteria.
- Groups either used an existing video or created ideas for a new video to exemplify these criteria.

FX (links): Video scoring criteria = rlrmc.barefootbob.net/wp-content/uploads/2018/08/GoodPracticesTVVideoContentScoringSpreadsheet.jpg

Groups' additional suggestions = rlrmc.barefootbob.net/wp-content/uploads/2018/08/URGroupSummaries.jpg

Scene 4: Carousel; Shot 1: Q1 Responses

Dialogue (paraphrased): Because people have short attention and retention spans, short videos can be most effective. (Alejandra, event participant)

Action (summary): Subgroups rotated to discuss and provide answers to these key questions:

- What characteristics make a video good or bad?
- Where can you find/shoot good videos?
- What can be done to optimally merge information dissemination and dialogue promotion in videos?

FX (links): table summaries of responses = rlrmc.barefootbob.net/wp-content/uploads/2018/08/CarouselActivityQ1.jpg rlrmc.barefootbob.net/wp-content/uploads/2018/08/CarouselActivityQ23.jpg

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#UR2018 had a collective reach of 12 million.


Photo: anyaberkut.

Influence.

116 Plenary *Communicating Urgency: Using Music to Convey Climate Change Data and Help Scientists Deliver the Message*

120 Early Warning for Early Action: Forewarned and Forearmed

126 Small Islands: Innovations in Understanding Risk

132 Learning from Mexico's Experience, 1985 to 2017

138 Public Policies for Disaster Risk Management in Mexico: Challenges in Implementing GIRD

144 Side event *Reaching the Last Mile: Challenges and Lessons from Early Warning Systems*

146 Side event *Risk-Informed Decision Making for Sustainable Development*

Performance of *Climate* at UR2018. Graphs showing data on climate change indicators are among the visuals that accompany the music. Photo: Miki Fernández

PLENARY

Communicating Urgency: Using Music to Convey Climate Change Data and Help Scientists Deliver the Message

The ClimateMusic Project (CMP) leverages the emotional power of music to educate audiences about the impact of human activities on the climate—and in turn inspire direct and meaningful personal action. People are aware that climate change is a significant concern, but too many still fail to recognize the magnitude of the problem and the urgency of taking immediate action at both local and global levels. There remains a small window of opportunity to avoid climate change's most potentially catastrophic consequences if we harness the individual and collective will to take urgent action.

CMP, a nonprofit collaboration of scientists, musicians, artists, and technology experts, seeks to close the knowledge-action gap through a "hearts and minds" approach designed to drive concrete action. Working with strategic partners, CMP facilitates active engagement on climate change through original musical compositions guided by widely accepted scientific data.

Our team of scientists from University of California–Berkeley and the Lawrence Berkeley National Laboratory is led by Dr. William Collins, senior scientist and division director, Climate and Ecosystem Sciences Division. Dr. Collins is also professor in residence at the Department of Earth and Planetary Science Division at UC Berkeley and director of the Climate Readiness Institute, and he has been a lead author on assessments by the Intergovernmental Panel on Climate Change (IPCC) for more than a decade.

In November 2015, CMP premiered its first composition, *Climate*, by Erik Ian Walker, a composer who has written and recorded music for theater, dance, film, and television. Since then, the piece has been performed at venues throughout the San Francisco Bay Area and enthusiastically received by audiences and reviewers.

CMP has successfully demonstrated that music, driven by science, has the power to convey a profound understanding of climate change among general audiences. CMP harnesses the deep understanding it creates by linking audiences to organizations engaged in direct solutions to the problem of a warming planet. Current partners include the Global Footprint Network, Cool Effect, San Francisco Office of the Environment, Interfaith Power and Light, and Re-Volv. Each focuses on an aspect of the solution—education, mitigation, or resilience.

The Musical Composition *Climate*

Climate tells the story of climate change over five centuries (1800–2250 AD), highlighting humanity's effect on the planet. It portrays our climate's trajectory under two scenarios—one with concerted intervention to reduce our carbon footprint, and an alternative depicting the consequences if we fail to intervene. The data sets that drive the composition come from simulations of the Community Earth System Model (CESM), an extensively used scientific model sponsored by the National Science Foundation and the U.S. Department of Energy.

Climate was composed by selecting four key indicators of climate change from widely accepted IPCC data and assigning each of those a musical analog:

- *Carbon dioxide concentration* is reflected in the *tempo* of the composition, with increasing amounts of CO_2 accumulating in the atmosphere causing the tempo to speed up.
- *Earth's atmospheric temperature* is represented by *pitch*, with a rise in temperature translating to detuning, increased dissonance, harmonic complexity, and/or a simple rise in pitch.
- *Earth's energy balance* (the balance between incoming energy from the sun and outgoing heat from the Earth) is audible as *distortion*, ring modulation (a wobbly metallic sound), volume, and a general "unhealthy" unevenness of the atmospheric tone. The greater the imbalance, the greater the distortion and loss of natural harmonics.
- *Ocean pH* is represented by *compositional form*. As the pH in the ocean drops (becomes more acidic), the compositional form degrades.
- The music itself is not generated by the climate data, but reflects them—that is, the composition is affected and changed by what the data describe.

Climate helps audiences understand both how the climate has changed in the last 200-plus years, and what we might expect in the future. The composition illustrates a choice: continue on our current path with potentially catastrophic effects, or work collectively to address climate change in the near term and so limit some of the consequences. The piece predominantly tracks "business as usual," in which we do little or nothing to rein in carbon emissions. This approach is projected to result in a rise in global temperature of 8–9°C and catastrophic impacts by the year 2250.

The two future scenarios are based on the simulations used by the IPCC, a scientific body under the auspices of the United Nations. Thus the way the music changes and the pace of change reflect the assessments—subjected to a rigorous review process—of climate scientists from around the world.

Performance at UR2018

At UR2018, conference attendees had the opportunity to experience a live performance of *Climate*. The music was performed by the composer, Erik Ian Walker, playing keyboard, and by the following musicians: Michèle Walther, violin; Thomas Dimuzio, synthesizer and live sampling; Scott Brazieal, keyboard; and Bill Noertker, bass guitar. Animations and video were produced by Dr. Andrew Jones, Darin Limvere, Kinetech Arts, and FXPAL. Stephan Crawford (founder of the ClimateMusic Project) and Fran Schulberg were executive producers who, along with Laurie Goldman, director of public engagement, organized the event with assistance from the World Bank Group.

Like all CMP's live performances, the concert at UR2018 included synchronized data and visual animations that contextualize our changing climate, and was followed by a public forum allowing audience members to interact with the project scientists, composers, and musicians to learn how they can engage productively. The UR2018 audience heard from William Collins and Erik Ian Walker, as well as James Balog, photographer and founder of the Extreme Ice Survey, and Stephan Crawford, founder of CMP. The panelists spoke about the need to communicate science in an unexpected or unusual way to get the public to engage actively. Music and visual art resonate in a way that scientific lectures or articles often fail to do and are thus an important tool for communication to broad audiences.

Plans for the ClimateMusic Project's Future

In cooperation with our partner, the San Francisco Conservatory of Music, CMP is seeking to reach broader audiences by working with respected musicians across the globe; our goal is to help them create climate music for their own communities. We also plan to create new non-live digital content with key partners FXPAL and Kinetech Arts.

In June 2018, we premiered a work for string quartet, *Icarus in Flight*, composed to reflect human drivers of climate change. We expect to debut additional music in 2019.

Since climate *action* is our focus, we are strategically expanding our network of partner organizations so we can provide audiences with direct engagement options immediately following our performances.

Our involvement with the Understanding Risk Forum provided an opportunity for CMP to showcase a different way of storytelling and for audience members to experience a new way to communicate climate science. Music is, after all, a universal language that reaches people from all walks of life and in all demographics. CMP demonstrates that leveraging the power of music can promote engagement with and make a difference in the critical and existential issue of climate change.

What do we want the future to sound like? Listen. Then act!

Further Resources

ClimateMusic Project. http://www.theclimatemusicproject.org/.

———. 2018. "The ClimateMusic Project: Second Half of the 20th Century" (video excerpt of *Climate*) https://youtu.be/6eRPANIpIXg. © ClimateMusic Project; permission is required for use of the video.

FXPal. https://www.fxpal.com/.

Kinetech Arts.org. http://kinetecharts.org/.

San Francisco Conservatory of Music. https://sfcm.edu/.

Session Contributors

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Scott Brazieal, keyboard
Bill Noertker, bass guitar
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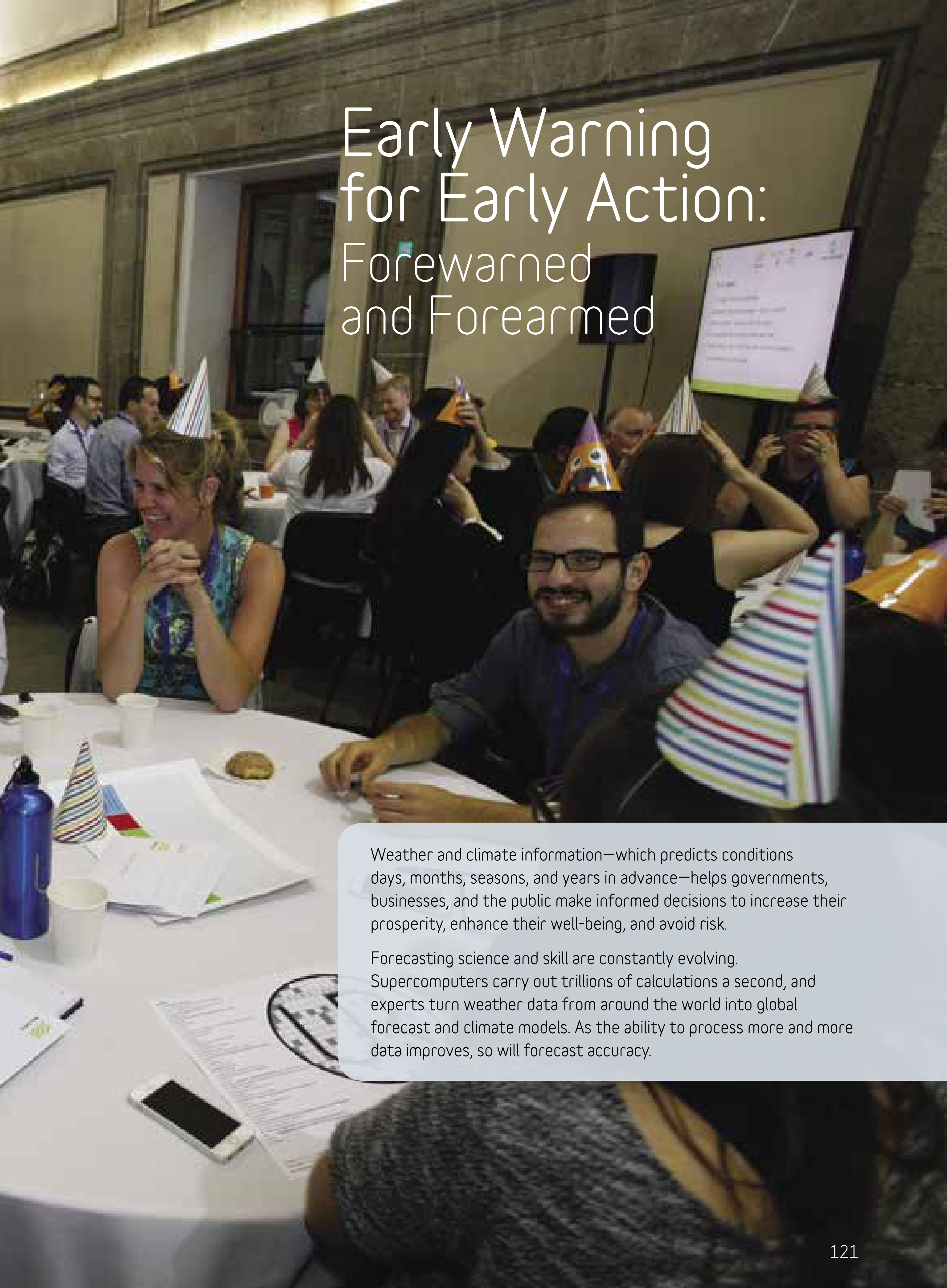
Andrew Jones, Climate Readiness Institute and Lawrence Berkeley National Laboratory
James Balog, photographer and founder of Extreme Ice Survey
Darin Limvere, documentary filmmaker
Stephan Crawford, ClimateMusic Project
Fran Schulberg, ClimateMusic Project

Over 800 paper origami pillars were constructed throughout UR2018.

Photo: Arturo Manrique.



Early Warning for Early Action:

Forewarned and Forearmed

Weather and climate information—which predicts conditions days, months, seasons, and years in advance—helps governments, businesses, and the public make informed decisions to increase their prosperity, enhance their well-being, and avoid risk.

Forecasting science and skill are constantly evolving. Supercomputers carry out trillions of calculations a second, and experts turn weather data from around the world into global forecast and climate models. As the ability to process more and more data improves, so will forecast accuracy.

Figure 1. Impact-based forecasting is a collaborative process incorporating hazard, exposure, and vulnerability information to establish the impact of weather and climate.

WHAT WILL THE WEATHER DO?

Hazard + Vulnerability + Exposure = IMPACT

Source: Met Office.

But even the most accurate forecast has no value unless it is used to guide decisions that lead to action. In recent years, impact-based forecasting has emerged as a technique for communicating the impacts that weather will have on people, livelihoods, and property, with the goal of helping decision makers mitigate risks and prepare for potential emergencies. Essentially, impact-based forecasting focuses on what the weather will do over what the weather will be.

Early action initiatives are starting to rely on impact-based forecasts to trigger funding (forecast-based financing), thus allowing for early action in the window of opportunity between the forecast and the potential disaster. This approach can mitigate risks, facilitate effective and less expensive disaster response and recovery efforts, and reduce impacts on vulnerable people. In short, acting in advance saves lives and money.

Here's Your Hat, What's Your Hurry?

This old saying harks back to a time when hats were commonplace. It was a jovial way to send people packing if they had overstayed their welcome. In the early warning/early action/disaster risk management community, we can play on this phrase to highlight the value of having the right information at the right time to best prepare for severe weather or climate events. Should you wear your hat or not? The "right information at the right time" can be produced only when information on hazard, exposure, and vulnerability is combined to shed light on the expected impacts of a severe weather or climate event (figure 1).

The UR2018 technical session on impact-based forecasting was jointly run by the Met Office, the Red Cross Red Crescent Climate Centre, and Deltares, agencies that respectively hold expert information on hazards, vulnerability, and exposure. It provided a perfect opportunity to test a gaming approach to early action planning. The overarching objectives of the session were to explain the importance of impact-based forecasting for effective and integrated management of risks across sectors; to share new ideas and contacts in order to inspire a new way of working; and to deepen participants' knowledge in order to promote effective action.

The Wearing of the Hats: The Game Begins

Following a brief introduction on impact-based forecasting, the session leads summarized how weather and climate information is increasingly being used to trigger preparedness efforts and enable earlier disaster risk response. Then it was time to put on the hats and start the game!

Game players took on different roles within a hypothetical community-based early action planning scenario in a fictional district called Magalu. Players were presented with a case study detailing the impacts of flood on life, property, health, and agriculture in Magalu, and were then asked to decide what actions they would take in advance to avoid or lessen these impacts if they had the right information.

The game had several aims:

- To explain forecast-based early action in an interactive and fun way
- To introduce the concepts of thresholds for action,

Session participants wear hats as part of a game to elucidate impact-based forecasting.

Photo: © Met Office.

triggers, no-regrets action, and uncertainty

- To illustrate the importance of cooperation among various stakeholders in building community resilience and agreeing on priorities for early action
- To demonstrate that support for forecast-based early action requires information on what the weather will do instead of what it will be

The roles in the game included the following:

- District Leader: Has responsibility for the district's flood preparedness; hosts the early action planning meeting
- Red Cross Red Crescent District Lead: Manages a team responsible for establishing fully equipped shelters in the lead-up to floods
- Agricultural Extension Worker: Encourages farmers to change their growing methods to avoid damage or losses to crops
- Disaster Risk Manager: Works with people to improve their knowledge of water hygiene and sanitation in emergencies
- Civil Society Representative: Feels angry at the lack of action and the needless loss of life and damage to property; wants to know how the District Leader plans to help the community
- Health Officer: Wants to ensure that adequate medical supplies are stocked to handle increased hospital admissions
- Director of National Meteorological and Hydrological Service (NMHS): Wants to improve meteorological and hydrological services by ensuring that weather and climate information meets users' needs

The ultimate task was to complete a forecast-based early action plan and outline the impacts of flooding on the district; see table 1 for a plan template and table 2 for a plan completed during the session. The information captured included (1) what action can be taken in advance to mitigate flood impacts, and when; (2) what information is needed to support the action; (3) who takes the action; and (4) what priority the action has relative to others.

Just before the end of the game, we presented a weather forecast that provided a bit more information on when the district could expect the floods to arrive. This helped the players to prioritize their actions, as did the knowledge of how little money was available for their preparedness activities ($100,000 overall from the national early action planning fund).

Table 1. Forecast-based Early Action Plan Template

What are the **IMPACTS?**	What **ACTION** can be taken in advance to mitigate these impacts and WHEN?	What **INFORMATION** is needed to support the action?	**WHO** takes the action?	PRIORITY 1 = highest 5 = lowest	*Other considerations (e.g. longer range actions, policy, interactions, etc.)*

Table 2. Completed Forecast-based Early Action Plan

What are the **IMPACTS?**	What **ACTION** can be taken in advance to mitigate these impacts and WHEN?	What **INFORMATION** is needed to support the action?	**WHO** takes the action?	PRIORITY 1 = highest 5 = lowest	*Other considerations (e.g. longer range actions, policy, interactions, etc.)*
INFRASTRUCTURE (lack of access, evacuation). Damage on houses & displacement	• Evacuation plans (routes). • Identify safe areas. • Strengthening infrastructure.	• Evacuation plans (routes). • Transport options.	DRM. MOH. Red Cross Local Council.	2	LT-strengthening infrastructure.
DAMAGE TO HOUSES AND DISPLACEMENT	• +10-20% (180 new shelters). • Review current stock of shelters. • House reinforcement.	• Population in need of shelter. • Safe location of shelters. • Info on available materials.	Red Cross.	1	LT-house reinforcement and relocation
HEALTH (medicine supplies, water supply, contamination)	• Ordering 2x a year. • Education awareness/ training. • Water tank availability.	• Inventory of existing supplies. • Information of clinic locations. • Types of medicines needed.	District Health. Local Council.	3	LT-maintaining supplies and building new clinics
AGRICULTURE (cattle, livestock)	• Identify safe/high areas. • Stock the cattle feed. • Transport options.	• Information on elevation, cattle, forecast.	Ministry of Agriculture. NHMS.	5	LT-crops on higher ground improving LT forecasts (NHMS)
LIVELIHOOD	• Water proofing of public docs. • Centralised system for public docs • Emergency cash transfer	• Priority list that needs ECT.	Local Council.	4	LT-centralised system
EDUCATION (student drop-outs)	• Education campaign.	• Bringing children back to school.	Schools.	5	LT-education development (curriculum)

IMPROVE MET & HYDRO FORECASTS

Keep Your Hat On: Fine-tuning the Game

We had tested the game repeatedly before the UR technical session to make sure it would be fit for a room full of diverse experts. We were hugely fortunate to secure facilitators from expert agencies such as DFID, the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR) hydromet team, Overseas Development Institute (ODI), German Red Cross, UK Environment Agency, and Climate Risk and Early Warning Systems (CREWS) Secretariat—in addition to our own colleagues. Their guidance and input helped us achieve a short (40-minute) time limit for the game and helped simplify and improve the game in other ways.

Developing this game was challenging because it addresses an extremely complex problem; multiple factors go into creating a robust early action plan. We had to provide just the right amount of information to ensure that discussions remained focused and that the value of working in partnership was evident. We decided to make the case study entirely and explicitly fictional in order to dispel participants' desire to "correct" the information. This approach also encouraged players to immerse themselves in their characters and the situation at hand.

We received two key recommendations for improving the game. One was to increase the amount of the early action fund to create a more competitive and realistic planning environment. The other was to shorten or translate the descriptions to allow non-native English speakers to participate more actively and confidently.

Fully Clothed

In the context of the game, "fully clothed" refers to the optimum scenario in which all the experts develop an early action plan. Their concerns about improving early action protocols are acknowledged, and their solutions are implemented. They have their hat but also their coat, gloves, and brolly!

The reality is not so ideal, however. Expert agencies have different capabilities that may or may not rely on ever-improving technologies and methodologies. For example: What if your NMHS cannot provide the lead time you need to prepare for a severe weather event (i.e., it takes eight days to purchase and build shelters but the NMHS provides a three-day lead time)? What if you need to order medication one month in advance and there is low confidence flooding will occur?

The game highlights the need for different agencies to work together to understand the challenges each one faces, and to create early action plans that are realistic—not ideal. Realistic plans can be regularly updated to allow for changes in circumstance and entail no-regrets measures, such as stocking hospitals in flood-prone districts with medications needed by flood victims.

The simplest way to develop a plan is to do so in silo—no one queries your approach and it's a lot quicker! However, such a plan will likely never be used, and if used will not be effective. This technical session confirmed the value of working in partnership for the overall good.

What's Next

Our technical session exceeded our expectations. Rather than being simply a fun conference activity with no lasting impact, the game has already been used by the Red Cross Red Crescent Climate Centre in Peru, the Met Office in Uganda, and Deltares in the Netherlands. It has also been more fully developed to include guidance and tools so it can be shared across agencies to support disaster risk activities.

Thank you to the Understanding Risk team and community for your help in developing and improving our forecast-based early action game! We invite readers to explore the wealth of resources associated with this work; see the list below as well as the more extensive compilation on the Understanding Risk website (at https://understandrisk.org/event-session/forewarned-and-forearmed/).

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Viti Levu, Fiji. Image: ESA.

Small Islands:

Innovations in Understanding Risk

Around the world, residents of Small Island Developing States (SIDS) are experiencing firsthand the impacts of climate change, losing their land and homes to erosion and hurricanes. Making decisions about how to reduce these impacts is not easy, and governments struggle to determine how best to prioritize actions and address citizens' concerns.

Acting on the challenges posed by climate change requires comprehensive quantitative risk assessments to inform decision makers. Although the size of SIDS makes them particularly vulnerable to climate change, it also makes them ideal for piloting comprehensive innovative methodologies to better understand risks and design resilience strategies.

Background and Concepts

SIDS are highly vulnerable to disasters and climate change. In addition to being located in areas prone to earthquakes, volcanos, and/or hurricanes, they are remote and economically fragile and have high levels of debt. Among countries with the highest disaster losses relative to gross domestic product (GDP), two-thirds are small island states, with annual losses between 1 percent and 9 percent of GDP on average. A single disaster can cripple an island's entire economy. Without tropical cyclones, for instance, Jamaica's economy could be expected to grow by as much as 4 percent per year; instead, over the past 40 years, it has grown 0.8 percent annually. Sometimes growth is wiped out all at once: when Hurricane Maria struck Dominica last year, it caused damage and losses equivalent to 226 percent of the country's GDP (Government of Dominica 2017).

SIDS are seizing the challenges posed by climate change with both hands. Taking advantage of their small size and aided by state-of-the-art technologies, governments are applying comprehensive quantitative risk assessments to better understand the risks they face, prioritize actions, and design resilient development projects. Assessments have been carried out at various scales, from global to national to local. The case studies presented below include a global assessment of sea-level rise as well as assessments for Fiji, the Marshall Islands, and Tuvalu.

Case Studies

Global projections of sea-level rise

Climate change is expected to increase extreme sea levels and flood risk along the world's coastlines. To assess these impacts, the integrated risk assessment tool LISCoAsT (Large Scale Integrated Sea-level and Coastal Assessment Tool) covers all the physical aspects driving coastal inundation and combines them with gridded projections of socioeconomic development considering different Shared Socioeconomic Pathways (SSPs). Results suggest that several of the Pacific and Caribbean SIDS are among the most affected countries as measured by the relative increase in the number of people exposed to flooding and expected annual damage. The Joint Research Centre of the European Commission, which developed the tool, will publish detailed results soon.

Fiji Climate Vulnerability Assessment

In Fiji, where most of the 900,000 inhabitants live on two islands totaling almost 16,000 km^2 in

Impacts of Tropical Cyclone Winston in Fiji. Photo credit: © Vlad Sokhin.

Marshall Islands. Photo: DanLinPhotography

the South Pacific Ocean, natural hazards and climate change are threatening the government's ambitious development goals and plans. The Fiji Climate Vulnerability Assessment (Government of Fiji, World Bank, and GFDRR 2017) presented by the Fiji government at the 2017 UN climate change conference (COP 23) quantifies and enhances the understanding of those risks.

The study considers two dimensions: (1) the physical threats to the country created by climate variability and climate change, including shocks such as tropical cyclones and floods as well as longer-term stressors like sea-level rise and impact on population; and (2) the country's development needs and opportunities, as described in the 5-year and 20-year national development plans. The analysis identifies threats that could jeopardize Fiji's development and suggests interventions to minimize these threats.

Results show that current impacts of tropical cyclones and floods will increase by up to 50 percent in 2050, when yearly losses could amount to 6.5 percent of GDP and push 32,400 people into poverty per year. The analysis proposes 125 interventions to help Fiji build resilience in five main areas, but they entail investment needs estimated at US$4.4 billion over 10 years, plus additional maintenance and operation costs and social expenditures.

Marshall Islands

The Pacific island of Ebeye, located on the Kwajalein Atoll of the Marshall Islands and lying only a few meters above sea level, is home to 40,000 inhabitants per square kilometer. It is the most densely populated island in the Pacific and the sixth most densely populated island in the world. A local, multi-hazard risk assessment of Ebeye modeled the impact of flooding, erosion, and sea-level rise using state-of-the-art numerical models for different return periods and time horizons. It found that annual damage to property and infrastructure on Ebeye could increase by a factor of three to four by the end of the century, according to standard Representative Concentration Pathway (RCP) scenarios for sea-level rise. Capping the temperature increase at 2°C, as required by the Paris Agreement, would reduce the consequences only slightly (Giardino, Nederhoff, and Vousdoukas 2018). The (cost) effectiveness of different interventions was also evaluated. This study informed the

Coastal areas in Tuvalu. Photo: © Alessio Giardino.

preparation of a US$49 million resilience project funded by the World Bank and the Green Climate Fund.

Tuvalu

Tuvalu's 11,000 inhabitants are spread across nine islands located between Australia and Hawaii and totaling only 26 km^2. Residents of Niutao and Nanumanga rely heavily on shipping to supply necessities but also to prepare for and respond to emergencies. A multi-hazard assessment was carried out for Niutao and Nanumanga to use as the basis for designing ship landing facilities (Deltares 2017b). New maritime infrastructures are expected to improve living standards for the local population and to increase the resilience of Tuvalu's maritime sector. Data analyses and numerical modeling were used to identify optimal locations and designs for these facilities and to assess their impact. The study's multi-criteria approach considered different types of wave conditions, the potential impact of the new planned infrastructure, expected sedimentation, and the local reef geometry. Results from this study are informing a US$20 million maritime transport project financed by the World Bank.

Challenges

SIDS seeking to build resilience and strengthen disaster response face several common challenges.

First, data for assessing climate and disaster may not be available. The resolution of global data or models is often too coarse for the small size of these islands, and the necessary local data may be of poor quality or incomplete. In addition, because individual small island nations are made up of multiple islands, data may be available for only part of the country. Second, relatively little is known about some of the processes affecting the SIDS environments. A third and significant challenge relates to the outsize impact that climate and socioeconomic changes will have on these very small and vulnerable islands. A final challenge relates to the accessibility to, logistics for, and local availability of resources needed to carry out studies in small islands.

On a national level, using results from risk assessments to prioritize effective and timely interventions is a challenge for SIDs, which face high levels of debt, scarce financial resources, and competing needs. Once prioritized, interventions can be impeded by human resource constraints and low capacity. In addition, recurrent adverse impacts tend to set back progress in socioeconomic and environmental development, and often force countries to use development funds for disaster response. As a result, islands regularly hit by extreme events such as hurricanes can find themselves stuck in a permanent repair mode, in which building ex ante resilience is difficult.

Recommendations

Given the large impact that climate and socioeconomic changes will have on SIDS, it is crucial that long-term planning strategies include adaptation and risk reduction solutions. Coordination between interventions and collaboration between national institutions and development partners will help SIDS build resilience and better respond to disasters. As part of risk reduction efforts, countries should identify a set of adaptation options that can be applied at different times in response to changing conditions, and should also support collection, storage, and sharing of data to clarify their risks and identify solutions for resilience.

Conclusions

The case studies presented above show that SIDS can overcome challenges in risk assessment. Using digital technology and numeric models, they can better understand the risks they face at diverse scales and obtain quantitative information to plan for a resilient future. Moreover, they can use their small size to their advantage to pilot innovative methodologies that can later be applied to larger countries.

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Coordination between interventions and collaboration between national institutions and development partners will help SIDS build resilience and better respond to disasters.

Plan Familiar
01
02
03
04
Consejos para
CONDUCIR BAJO LA LLUVIA
TIPS
Emergencias
066
después de un Huracán
Antes
CUANDO LA TIERRA SE MUEVE
Incendio
Desastres Naturales
Elabora tu Plan Familiar de Protección Civil
PLAN FAMILIAR DE PROTECCIÓN CIVIL
Tu participación es tu protección
CDMX
Recomendaciones
QUÉ HACER DURANTE LA ÉPOCA DE FRÍO
PLAN FAMILIAR DE PROTECCIÓN CIVIL
Porque la seguridad empieza en casa... prepara un plan de protección civil con tu familia
Mochila de Emergencia
Sigue estos 4 pasos
Infórmate
PREPARA
PLAN FAMILI
PROTECCIÓN

Learning from Mexico's Experience, 1985 to 2017

Mexico's National System of Civil Protection (SINAPROC) was founded in 1986 in response to the devastating 1985 Mexico City earthquake. In the years since then, which have included numerous tropical cyclones, earthquakes, and other hazard events, SINAPROC has accumulated and used a wealth of disaster risk information and has developed multiple social protection tools. In addition, under the president's leadership, the three levels of government (national, state, and municipal) have coordinated efforts to ensure rapid emergency response and immediate post-disaster reconstruction. Post-disaster processes have also been revised over time to help SINAPROC further reduce disaster impacts and better administer emergency response. These efforts have emphasized the importance of coordination as a cross-cutting element that reduces response time, makes government's actions more efficient, and improves government's cooperation with the private sector and civil society.

This UR2018 session, coordinated by the National Center for Disaster Prevention (Centro Nacional de Prevención de Desastres, or CENAPRED), brought together presenters from different sectors to share information on new technologies and lessons learned that have improved disaster risk communication and management in Mexico in the period 1985 to 2017. The session also looked at possible future scenarios the country might face.

Background to Disaster Risk Management in Mexico

SINAPROC was created with the aim of developing Mexico's civil protection capacities, which had been non-existent during the 1985 earthquake. That event showed the need for a comprehensive and systematic approach to disaster response that could coordinate multiple actors. Under Mexico's civil protection model, SINAPROC serves as a coordinating entity for institutions, functional relations, and programs; it seeks to strengthen the capacities of and links between civil protection efforts in the public, private, and civic sectors.

Over the last 25 years, SINAPROC has developed and improved disaster planning, response, and recovery capacities, as was evident when another powerful earthquake struck Mexico City in 2017. Like many other countries, Mexico has succeeded in reducing the annual casualties caused by disasters, but the economic impacts of disasters have increased.

With passage of the General Law of Civil Protection of 2012, Mexico has sought to change and improve its civil protection model. The Comprehensive Disaster Risk Management (Gestión Integral del Riesgo de Desastres, or GIRD) approach now serves as the analytical framework for all public policy making in disaster risk management (DRM). The GIRD approach has been given this prominence because it entails not just action-based change, but also conceptual change—that is, in accordance with the Sendai Framework for Action 2015-2030,

Earthquake drill in Mexico City. Photo: Reuters.

it emphasizes risk reduction over emergency response and seeks a coordinated, cross-sectoral effort from all levels of government.

Improvements in Mexico's DRM System: Case Studies

The session's first presentation, by Allen Husker of the National Autonomous University of Mexico (UNAM) Seismology Department, described Mexico's seismic risks and possible scenarios for seismic events. It also addressed seismic monitoring tools developed by Mexico, mainly through the National Seismic Service and through projects like the Mexican Seismic Network, which over the last six years have helped improve identification of seismic events. Finally, it addressed the need to increase the number of seismologists so that research could be carried out on focal mechanisms, seismic gaps, and other topics in need of greater study.

The second presentation, by Sergio Alcocer of Mexico City's Advisory Committee on Structural Safety, explained how structural engineering principles are applied to conduct post-seismic evaluations. Mexico's College of Civil Engineers initiated the process used for this purpose, which was later followed by the Structural Engineering Society, UNAM's Engineering Institute, and the Metropolitan Autonomous University (UAM). The evaluation process required organizing brigades of engineers to conduct multiple (sometimes over 1,000) inspections of buildings in the affected area. The findings have suggested the importance of developing a strategic plan to reduce seismic risk in Mexico City.

In the third presentation, Oscar E. Vela-Treviño of the Secretariat of Finance and Public Credit (Secretaría de Haciena y Crédito Público, or SHCP) described Mexico's Natural Disaster Fund (FONDEN), a financial tool that allocates resources for emergency response and post-disaster reconstruction. This fiscal year, FONDEN should receive no less than 0.4 percent of Mexico's annual budget; in 2017, annual budgeting for FONDEN was Mex$8,245 million. This presentation also described catastrophe bonds, a risk transfer mechanism that is activated—supplies resources from FONDEN—when disaster damages are verified and losses exceed a certain threshold. Such tools for financial management of disaster risk help Mexico maintain the stability of public finances.

Challenges under the GIRD Model

The presentations identified at least two challenges faced under the GIRD model.

First is the challenge of ensuring that the different civil protection services work effectively at the three government levels (federal, state, and municipal), and that they work flexibly with one another and with relevant businesses, civil society organizations, and research institutes. Meeting this challenge would help the institutions that are part of SINAPROC strengthen their capacities to prevent disasters and reduce vulnerability, while also contributing to sustained economic development.

A second challenge is to allocate more funding for disaster prevention than for disaster relief, and to impose greater transparency and accountability on related decisions and processes. Mexico's emergency relief, reconstruction, and risk transfer tools have been successful; indeed, FONDEN has served as a model for countries worldwide. But meeting this challenge would make them even more effective.

Recommendations

Several recommendations emerged from the session:

- To prevent and reduce disaster risks at the three government levels, and to promote a comprehensive disaster management approach, Mexico should continue to foster cross-cutting public policies.
- SINAPROC has sought to push states and municipal governments to undertake data collection. Entities at all levels should maintain and make use of risk atlases as a strategic and indispensable tool for territorial planning and urban development.
- Disaster risk management policies should be subject

to continuous evaluation and should be based in the principles of co-responsibility, transparency, efficiency, and equality.

- The implementation of the General Law of Civil Protection should be strengthened. This process is critical for identifying priorities that help align subnational programs with federal programs and for promoting disaster risk management at the local level.

Conclusion

Since its creation in the aftermath of the 1985 Mexico City earthquake, SINAPROC has sought to improve Mexico's ability to plan for, respond to, and recover from disasters. Through CENAPRED, SINAPROC has sought to motivate risk evaluation by promoting tools for collecting and analyzing data on hazards, vulnerability, and exposure. It has also provided guidelines and technical assistance to states and municipalities to ensure that they create risk atlases, and that these atlases function as useful tools rather than just hazard inventories.

CENAPRED has implemented a public policy that seeks to reduce seismic risk through four different cross-cutting instruments: applied research, National Risk Atlas, National School of Civil Protection, and civil protection culture. Each of these instruments has consolidated preventive efforts at the national level, so that knowledge, dissemination of knowledge, and disaster preparation will serve as cross-cutting elements that strengthen CENAPRED's capabilities.

Mexico's efforts to improve disaster risk prevention, preparedness, and response are ongoing, and the government will continue to develop and make use of new knowledge, methods, and tools in the coming decades.

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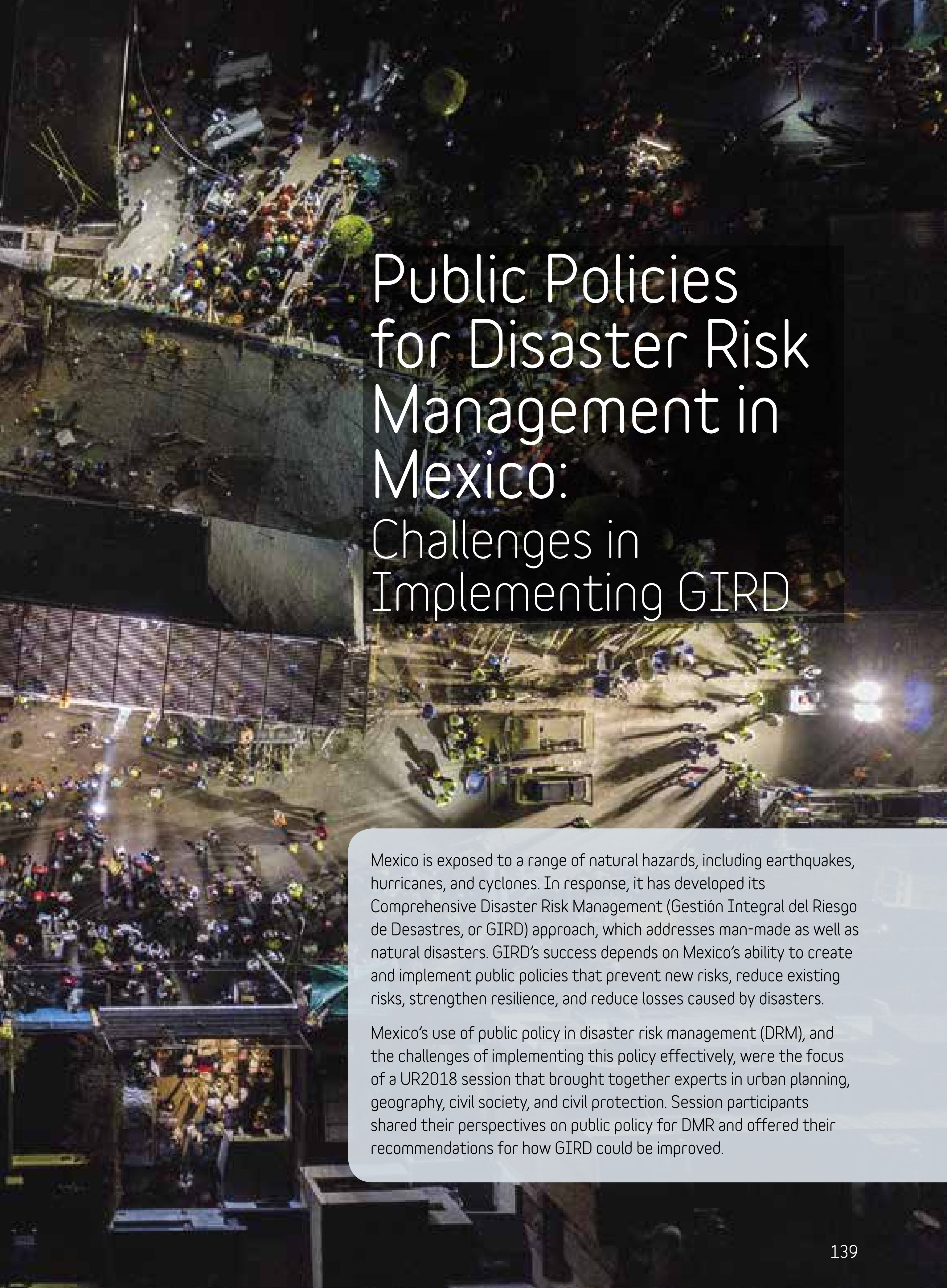
#UR2018 was used over 5,500 times during the five-day forum.

Mexico: Aerial view of the work of the rescue teams in a collapsed building. Photo credit: Manuel Velasquez/Anadolu Agency/Getty Images.



Public Policies for Disaster Risk Management in Mexico:

Challenges in Implementing GIRD

Mexico is exposed to a range of natural hazards, including earthquakes, hurricanes, and cyclones. In response, it has developed its Comprehensive Disaster Risk Management (Gestión Integral del Riesgo de Desastres, or GIRD) approach, which addresses man-made as well as natural disasters. GIRD's success depends on Mexico's ability to create and implement public policies that prevent new risks, reduce existing risks, strengthen resilience, and reduce losses caused by disasters.

Mexico's use of public policy in disaster risk management (DRM), and the challenges of implementing this policy effectively, were the focus of a UR2018 session that brought together experts in urban planning, geography, civil society, and civil protection. Session participants shared their perspectives on public policy for DMR and offered their recommendations for how GIRD could be improved.

Mexico's GIRD Approach

Mexico's GIRD approach seeks to make DRM truly comprehensive and integrated. It was designed to link government decision making across different sectors, including land use planning, environment, housing, and gender, among others. It serves as the cornerstone of Mexico's General Law of Civil Protection (2012), which emphasizes disaster risk prevention but also acknowledges the need for disaster and emergency preparedness.

GIRD lays out a system for decision making that rests on several key principles:

- *Efficiency and equality.* These ensure that DRM activities are beneficial, and that they equally benefit all groups. The goal is to disentangle disaster risk at its different phases, including response, recovery, and reconstruction; place them under the rubrics of resiliency, adaptation, mitigation, and prevention; and by giving these elements the same priority, make DRM more efficient.
- *Comprehensive view of risk.* This entails ongoing feedback of knowledge on natural threats into the system, and encompasses the most appropriate actions to mitigate the vulnerability of people and exposure of property.
- *Cross-cutting capacities.* This principle calls for treating disaster risk reduction across sectors, such as civil protection, environment, local territories, social development, and education. The purpose is to promote risk transfer knowledge and coherent actions by the public sector, insurance agencies, etc.
- *Joint responsibility.* This principle is based on an understanding of risk as socially constructed—that is, one that sees all social actors, both large and small, as having a role in constructing risk.
- *Transparency and accountability.* These are required by the social construction of risk and should be part of program implementation, mitigation plans, and risk prevention; they are further needed to ensure efficient and equitable resource allocation.

Challenges in Implementing GIRD

Implementation of this complex tool began with efforts to ensure that all government sectors understood the topic and the emphasis on disaster prevention. Before passage of the General Law of Civil Protection, a common view was that civil protection was the only sector that dealt with emergencies and disasters; indeed, the civil protection focus on disaster relief over disaster prevention is still evident at the local level. Thus an initial challenge in implementing GIRD involved the training of DRM staff at all levels to follow GIRD's mandate.

The main challenge that GIRD faces currently is to implement its key principles (outlined above) in the context of daily decision making. The expectation is that under GIRD, responsible decisions can untangle the multiplying effects generated by the social construction of risk processes.

Session participants noted several areas where GIRD's implementation could be improved. They observed that implementing the Sendai Framework for Disaster Risk Reduction would be helpful for GIRD in that it would improve understanding of disaster risk at different territorial scales. This in turn would provide information needed for early warning systems and for improved local government decision making. Implementation of GIRD could also be strengthened by better knowledge of the links between science, technology, and public policy, which is necessary for reducing social vulnerability. Finally, meeting the Sustainable Development Goals could help address vulnerability issues and the exposure of different communities, although meeting these goals would require greater cross-cutting capacity at all levels, from the international to the national and local.

A key function of GIRD is to conduct evaluations of the decisions made by the government. This function, designed in part to support integration of different DRM components in large-scale projects and policies, requires consistency between public policy and the epistemology of knowledge—in other words,

Frida the rescue dog is part of the Secretaría de Marina of Mexico. She supported the rescue effort after the September 19, 2017, earthquake and was welcomed on stage at UR2018. Photo: Twitter@gobmx.

knowing the policy's effect should be considered inseparable from implementing the policy. A policy that is not evaluated remains a dead letter. Participants noted that evaluations can identify errors, teach lessons, and help correct and improve both the regulatory framework and specific tools used within it.

Participants also noted the importance of diagnostics in policy implementation. Where diagnostics reflect reality, there is a greater probability of successful results. Where diagnostics are incomplete, however, there is a greater chance of errors and problems.

GIRD could also be improved by studying previous decision-making errors; using the regulatory framework as a reference, decision makers could identify the reasoning behind the error and understand how to close the gap between rule and implementation in the future.

Finally, it was noted that as part of broader public administration, the process of developing public policies for DRM is the government's responsibility. Thus the government must understand and adhere to best practices in DRM in order to obtain good results.

Conclusions

A far-reaching public policy like GIRD requires creativity and imagination on the one hand, and industriousness and ethics on the other. Creativity and imagination are required for identifying and addressing social issues. Industriousness is needed to gain in-depth and accurate knowledge of different implementation disciplines. Ethics is critically important for ensuring a realistic implementation and consistent legislation.

Public policy in civil protection must be interdisciplinary, and this is especially true for GIRD. Mexico should be asking itself some crucial questions about civil protection: Are the current policy tools for civil protection enough? How has the Civil Protection Agency performed? What are its tasks, and do these tasks correspond its functions?

Participants concluded that it is possible to carry out an in-depth analysis of public policy that allows the government to formulate an approach to influencing human behavior, whether through prescribing best practices or penalizing bad practices. In reality, however, decision making is often realized through a political document that understands implementation in legal terms. While some political instruments operating with a legal framework can be effective as law, they may also be ineffective as actually carried out. This is why decision makers must be aware of and understand the effects of public policies, which can be identified through evaluation and through ongoing dialogue among scientists and technology experts. This is also why it is crucial to have public policies and laws that the public trusts. If these goals are not met, Mexico will continue to be at risk of reliving painful and even deadly experiences, like the September 1985 and September 2017 earthquakes.

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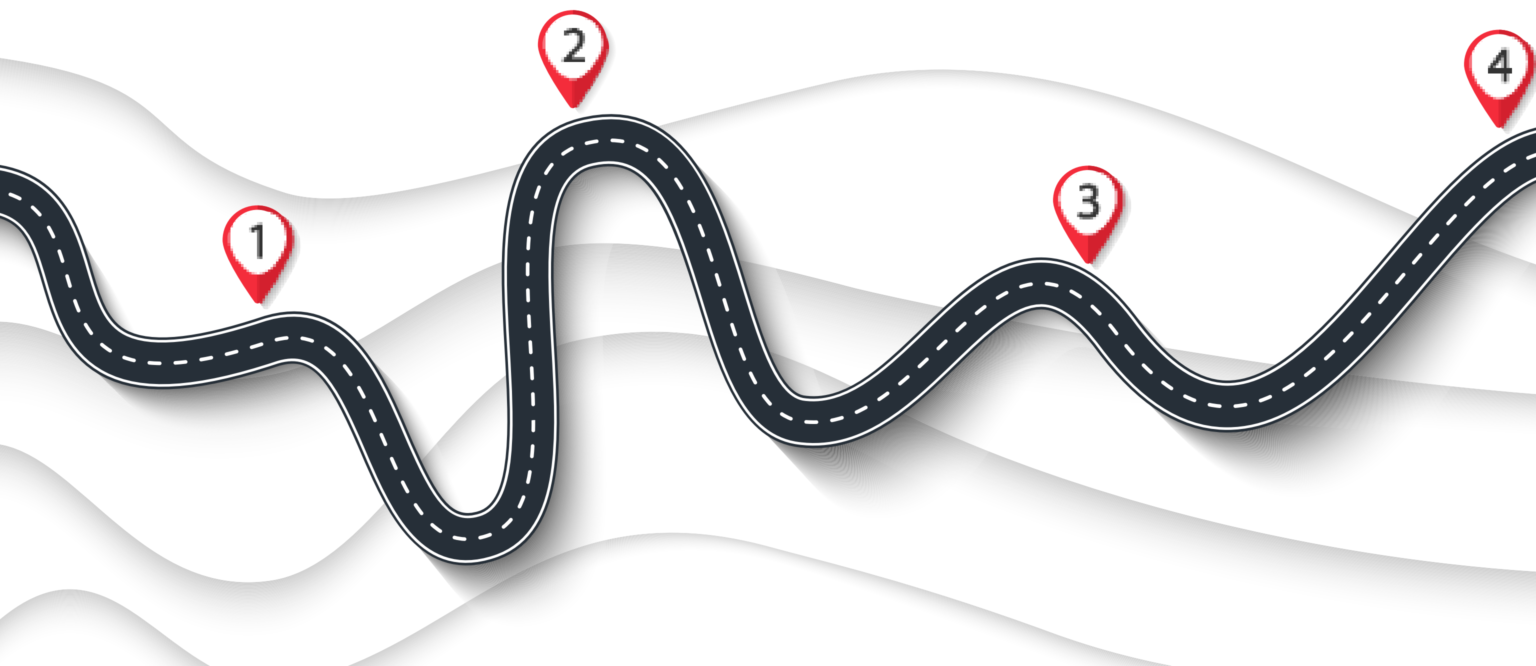
Decision makers must be aware of and understand the effects of public policies, which can be identified through evaluation and through ongoing dialogue among scientists and technology experts.

The UR app was used for 38,700 minutes.
561 app users exchanged credentials with each other.
The app had 658 users.



Side Event

Reaching the Last Mile: Challenges and Lessons from Early Warning Systems

Within the flood management cycle, early warning systems are essential tools for saving lives and livelihoods. Effective end-mile impact requires that flood information can reach everyone—and that the needs, capacities, and priorities of both men and women are considered in all components of the system. Marginalized populations (such as women, children, the elderly, and the disabled) are often overlooked by disaster risk reduction strategies; these groups require special consideration and attention to ensure they are not left behind. A range of factors within vulnerable communities—including individuals' age, gender, ethnicity, literacy level, physical capacity, and poverty—affects whether people can access, understand, and respond to information.

During this UR2018 event, Practical Action staff shared lessons from their experiences with early warning systems. Their work in Nepal and Peru, for example, has showed that women and men often have different roles in evacuation. Their work also shows that women may experience unique difficulties evacuating, such as challenges related to their clothing, hair length, caring roles and responsibilities, lesser physical strength, and inability to swim. Perhaps because of these challenges, women prefer to evacuate earlier than men. However, where women lack decision-making power, they are often unable to take action until men decide to evacuate, by which time evacuation routes are more dangerous, particularly for women.

Lisa Robinson of BBC Media Action described her organization's partnership with a local radio station in Bangladesh, Oromia Radio, to broadcast a short magazine program that offers practical advice on agriculture, water, sanitation, and shelter. BBC Media Action has also broadcast a reality television series that visits vulnerable communities as they work with their neighbors and local government to build their resilience. Audiences trust this information because it is in their native language, specific to their location, and easy to understand. As a result, people use this information to make decisions.

At the other delivery end, the UK Met Office is working to build the capacity of national meteorological services in hazard-prone countries. Nyree Pinder highlighted the role of meteorological agencies in identifying and communicating risk as they work within the government to protect lives and livelihoods. Through a range of programs, the UK Met Office is working to

More generally, context will affect how early warning systems are managed (i.e., locally or nationally), how thresholds for alerting and taking action are defined, and how warning information is shared.

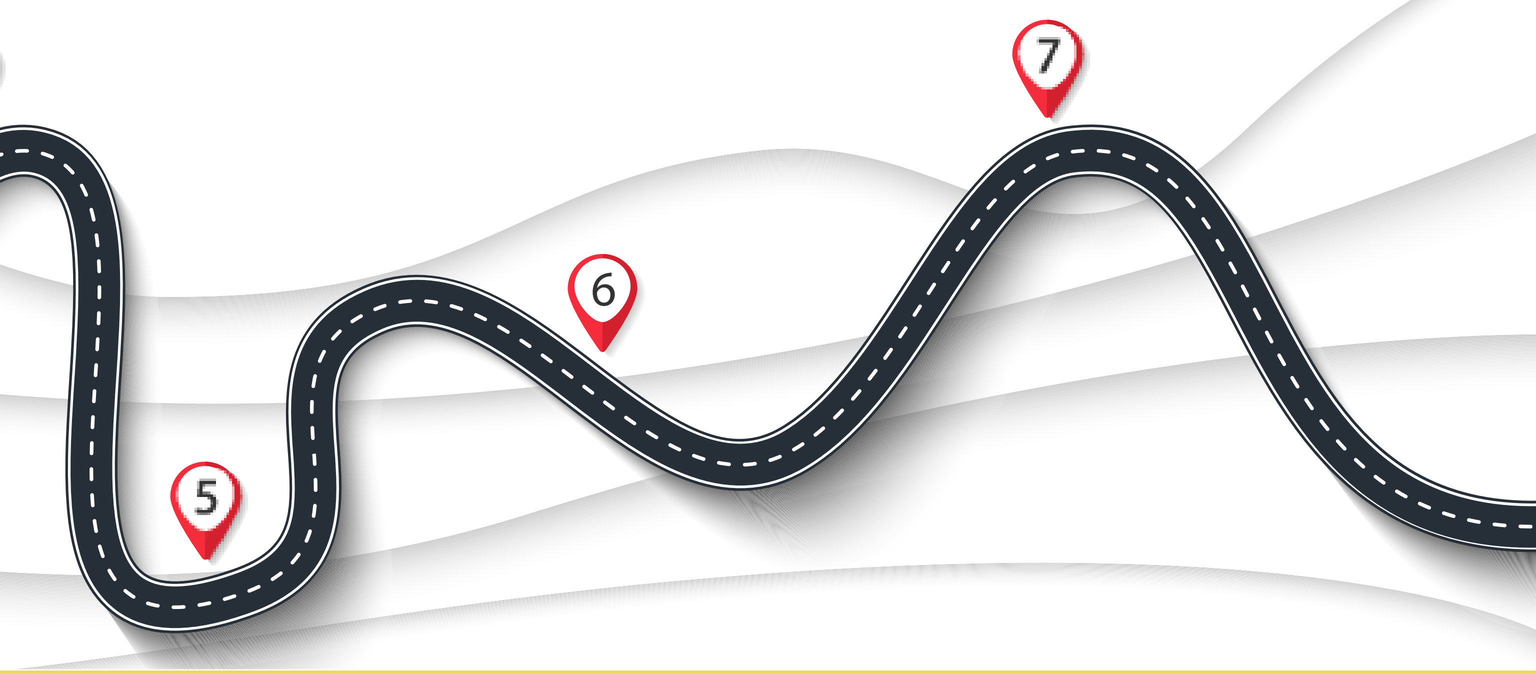


Illustration: zmicierkavabata

help national and regional meteorological services provide better climate information services. It is moving toward impact-based forecasting to better meet the needs of vulnerable communities.

David Lau of Soluciones Prácticas highlighted work in Peru to build resilience: solar-powered field monitoring stations have been installed to measure rainfall using photographs and soil saturation, and community groups (brigades) have been formed (and supported) to use these stations, issue evacuation alerts, and conduct drills. When knowledge is owned and trusted by the community in this way, there is support for improved resilience in the long term.

Mathieu Destrooper of the German Red Cross demonstrated how the early warning system in Peru could be improved to give vulnerable communities more time to prepare: combining upstream water levels, rain forecasts, and soil moisture levels could increase the lead time—currently one to five hours—to one to five days. Peru faces key questions about how to guarantee that early action is taken at the community level. More generally, context will affect how early warning systems are managed (i.e., locally or nationally), how thresholds for alerting and taking action are defined, and how warning information is shared.

The session brought together a range of voices, perspectives, and experiences on reaching the last mile. Working in different countries, with different stakeholders, and at different levels, our panelists are engaged with national and local government, with media, and directly with community members. But across this broad range of experience, one point emerged repeatedly: a multitude of factors affects people's vulnerability to and experience of disasters. Our work on early warning systems must be context-specific and tailored to the needs of the people who have to respond to warnings in order to ensure action is taken and lives are saved.

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Side Event

Risk-Informed Decision Making for Sustainable Development

Risk-blind development continues to drive disaster risks and offset development gains. This fact is affirmed in the 2030 Agenda for Sustainable Development, which recognizes that "more frequent and intense natural disasters . . . threaten to reverse much of the development progress made in recent decades" (United Nations 2015). It also underlies the Sendai Framework's Priority 3, "investing in disaster risk reduction for resilience," which recognizes the connection of risk with development.

Risk is not exogenous to development; rather, development itself is a key driver of risk. Hence it is imperative that both public and private actors systematically assess risks (hazards, exposure, vulnerabilities, and capacities) and generate comprehensive risk information as an evidence base for risk-informed development processes. Investing in the collection and dissemination of risk information will help ensure that decision makers and policy makers can access that information in an easy-to-understand format. It will also facilitate the application of risk information to development processes and help in the design of accountability mechanisms as part of strengthened disaster/climate risk governance.

Viewing risk-informed decision making as a critical priority, the United Nations Development Programme (UNDP) organized an event at UR2018 to share relevant experiences and lessons from a range of practitioners and stakeholders, including the Global Centre for Disaster Statistics of Tohoku University, Global Facility for Disaster Reduction and Recovery, Global Earthquake Model, and Government of Uganda.

Participants emphasized the centrality of the risk information cycle and its four stages: (1) generation of risk information through evidence-based risk assessments and modeling; (2) risk management by providing dynamic risk profiling; (3) risk communication and dissemination in user-friendly formats and visualizations; and (4) use/application of risk information through effective risk governance institutions and systems at national and sectoral levels. This discussion was complemented by country examples from UNDP's support for actionable risk information at national and subnational levels.

The first step in the risk information cycle is to generate an evidence base through data and statistical analysis and use it to inform policy making and risk mainstreaming. The Global Centre for Disaster Statistics initiative, part of the Government of Japan–UNDP partnership, is supporting the institutionalization of global and national disaster databases. The goal is to help countries establish baselines for monitoring and reporting, develop capacities needed for a national disaster statistics system, and promote risk-informed development. The initiative also supports countries in carrying out an empirical stocktake of their risk landscape and in tracking the progress of targets under the Sendai Framework and the Sustainable Development Goals.

Photo: bauhaus1000.

Next, it is essential to develop risk information and communicate it in a form that end-users understand. The context-specific risk profiles will help identify risk management options along with their costs and benefits. The development sectors should be encouraged to participate in the process of generating risk information by developing risk profiles, sharing these to meet contextual needs, providing risk analysis that is understandable to users, and supporting management of risks.

It is also critical to adopt a proper risk assessment process to promote greater local ownership, while also ensuring that risk assessments move beyond identifying risks to generating information to support possible solutions.

Finally, risk information must be applied in development decision making. Increasingly, governments such as the Government of Uganda are successfully applying risk information—using tools like risk profiling, risk atlases, integrated early warning systems, crop monitoring, and food security assessments—to foster risk-informed development.

Disaster and climate risk management practitioners must ensure that contextually appropriate and actionable risk information is available to decision makers. The process of generating risk information must identify relevant, easy-to-understand, and context-specific solutions in order to foster use of risk information and help mainstream it into development planning and implementation at all levels. It must also involve all stakeholders and sectors to ensure greater buy-in and support at the time of its application.

In short, effective risk management and risk-informed decision making require a comprehensive loop spanning generation, communication, and application of risk information.

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John Schneider, Global Earthquake Model

What is Understanding Risk?

Understanding Risk (UR) is an open and global community of over 8,000 experts and practitioners interested and active in the creation, communication, and use of disaster risk information. This vibrant community—a diverse group of people from the private, public, nonprofit, technology, and financial sectors—meets at the UR global forum every two years. Each iteration of the UR Forum has produced new ideas and partnerships that have improved risk information and helped to integrate evidence into policy making and development planning.

This publication captures the experiences, lessons, and best practices in the field discussed at the fifth UR Forum, held in Mexico City, from May 18 to May 22, 2018.

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