2016

Understanding Risk

Building Evidence for Action

Proceedings from the 2016 UR Forum

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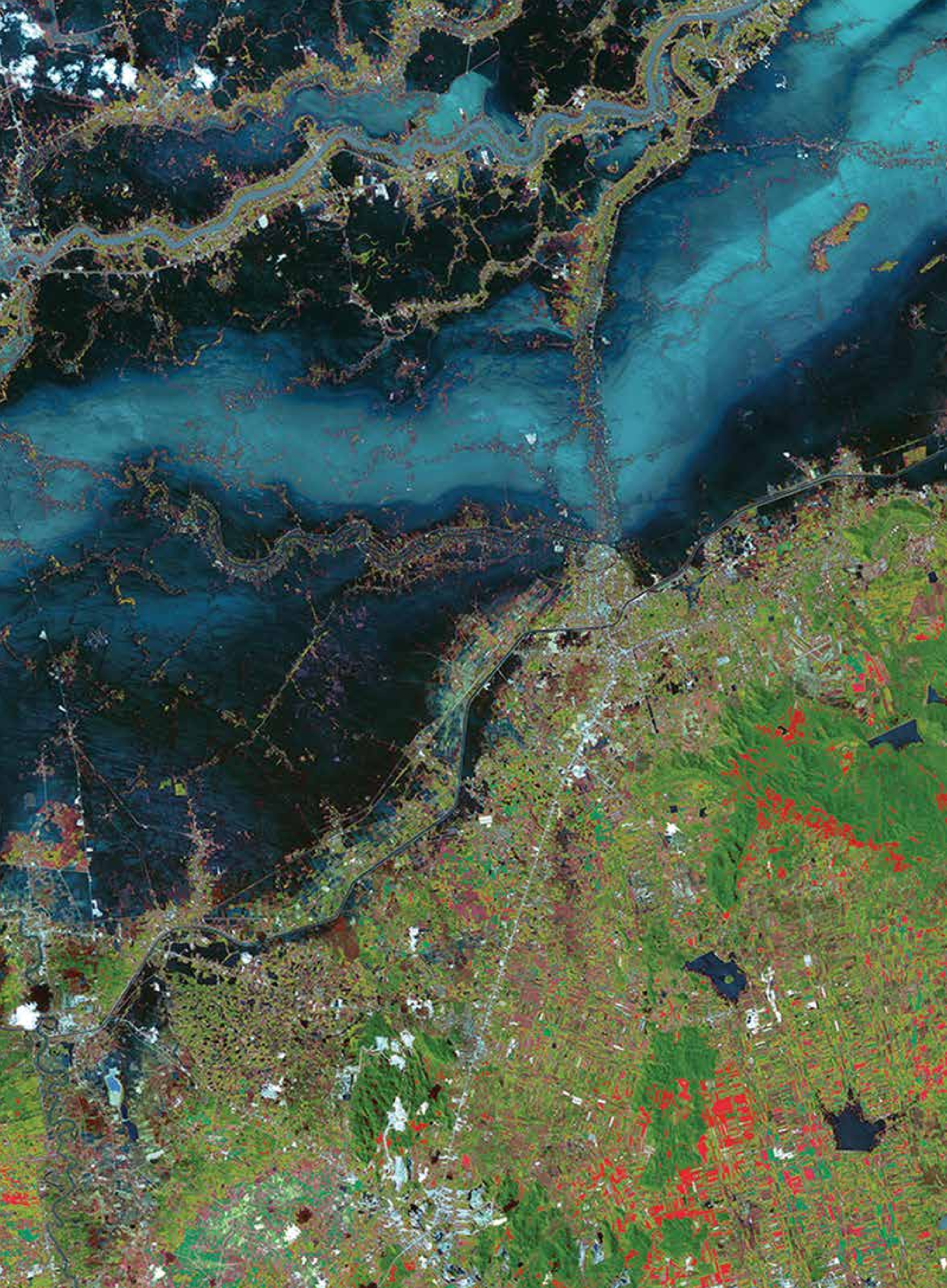
Photo: On October 23, 2011 the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument on NASA's Terra spacecraft captured the flood waters that were approaching Bangkok, Thailand as the Ayutthaya River overflowed its banks. Photo credit: NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.



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Acknowledgments

The energy and dynamism felt at the fourth global UR Forum would not have been possible without the continued support and enthusiasm of the UR community and those who came to Venice. Thank you for continually coming to UR events to contribute your passion, knowledge, and creativity to this important field.

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The UR core team—Francis Ghesquiere, Alanna Simpson, Emma Phillips,
Joaquin Toro, Simone Balog, and Julie Aaserud

Foreword

The fourth edition of the Understanding Risk Forum (UR2016) was a resounding success, bringing together practitioners from more than 100 countries to meet, learn, and share best practices. This was our most ambitious and global forum yet. More than 2,000 meetings and networking opportunities saw policy makers, risk modelers, urban planners, economists, psychologists, communicators, and others meet in the inspiring setting of the 12th-century Venetian Arsenale.

The city of Venice hosted UR2016 with grace and hospitality, offering an inspiring location to showcase what is at stake in risk management, as well as all the advances that we as a community have achieved over seven years.

Participants kicked off the week with some 40 Focus Day activities, from learning to build a mobile weather station to creating a new community of practice for climate resilience in small island states.

On Wednesday, session leads welcomed participants to UR2016 through a series of Ignite Talks. Amal Ali passionately described how new technologies could disrupt the disaster risk management field, telling of how her own relatives in Somalia may be able to live more sustainably. Hessel Winsemius, a veteran of UR, convinced us of the need to address cascading hazards if we are to truly understand risk.

The following days were packed with fascinating sessions as well as ample time to network within and across professional fields.

In an intensely interactive session, Pablo Suarez led a series of games that inspired us to examine just how we make decisions, and how framing risks differently can influence reactions, decisions, and outcomes. A new "MapSlam" session, inspired by poetry slams, saw two individuals go head-to-head to communicate information on El Niño and La Niña.

We learned lessons from Mozambique, the Philippines, and the United Kingdom on incorporating impact-based forecasting—including a recommendation to build a community of practice in this field that could be hosted at the next UR Forum. In a first for UR forums, the session "Communicating for Action" used the Glisser platform, a tool that allows for live engagement with audiences during presentations.

A little over a year since the devastating earthquake in Nepal, Nama Budhathoki shared lessons on incorporating data collection and management into projects now, before a disaster strikes, to enable better response when the worst does happen. John Roome led us through a Hard Talk with leaders in the insurance industry, the humanitarian sector, and a space agency. One thread was constant: we must continue to engage with stakeholders across all fields to build alliances that can drive understanding and action.

Maybe the main innovations presented this year were in the area of big data and social media analytics. Several speakers showed how social media can be used to improve early warning systems, to map vulnerable infrastructure, or to monitor reconstruction programs. We are excited to track how this growing field evolves by our next forum in 2018.

This forum saw the launch of many publications and tools. Among them, *The Making of a Riskier Future* underscores the need for future risks to be integrated into today's development planning to prevent our growth patterns from concentrating assets and populations in the most threatened locations.

Some highlights from the forum are not captured in these pages yet enriched the experience: Sheryl Sandberg, COO of Facebook, participated by video to launch our dialog on gender; futurist Jamais Cascio showed us that there continues to be good in the world; and participants released 300 butterflies above the canals of Venice as part of an effort to build corridors of sustainability.

The success of UR2016 would not have been possible without the contribution of many individuals and organizations from around the world. We thank you for your generosity, curiosity, and passion!

We hope you enjoy these UR2016 proceedings, and look forward to what's to come in the next two years before UR2018. See you then!

Francis Ghesquiere
Head, GFDRR Secretariat

Abbreviations

1BC	One Billion Coalition for Resilience
CGE	computable general equilibrium
DRM	disaster risk management
DRMKC	Disaster Risk Management Knowledge Centre
DRR	disaster risk reduction
ECHO	Directorate-General for European Civil Protection and Humanitarian Aid Operations
EU	European Union
FEMA	Federal Emergency Management Agency
FOREWARN	Forecast-based Warning Analysis and Response Network
GEM	Global Earthquake Model
GFDRR	Global Facility for Disaster Reduction and Recovery
GFP	Global Flood Partnership
GIS	geographic information system
GTM	Global Tsunami Model
GVM	Global Volcano Model
HOT	Humanitarian OpenStreetMap Team
IAM	integrated assessment model
IBLI	index-based livestock insurance
ICL	International Consortium on Landslides
IO	input-output
IRI	International Research Institute for Climate and Society
KLL	Kathmandu Living Labs
KNMI	Royal Netherlands Meteorological Institute
MASDAP	Malawi Spatial Data Portal

MoU	memorandum of understanding
NOAH	National Operational Assessment of Hazards
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OECD	Organisation for Economic Co-operation and Development
OpenDRI	Open Data for Resilience Initiative
OSM	OpenStreetMap
PacRIS	Pacific Risk Information System
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PARIS21	Partnership in Statistics for Development in the 21st Century
PCRAFI	Pacific Catastrophe Risk Assessment and Financing Initiative
PHE	Public Health England
PIP	prioritized investment plan
SIDA	structural integrity and damage assessment
SOPAC	SPC Applied GeoScience and Technology Division
SOPs	standard operating procedures
SPC	Secretariat of the Pacific Community
STAG	Scientific and Technical Advisory Group
UNEP GRID	United Nations Environment Programme Global Resource Information Database
UNISDR	United Nations Office for Disaster Risk Reduction
UR	Understanding Risk
USAID	U.S. Agency for International Development
WMO	World Meteorological Organization

All dollar amounts are U.S. dollars unless otherwise indicated.

5 days in Venice

57
sessions

41%
female participation

2000
meetings

101
countries represented

350
organizations

300
butterflies released

Overview

The Understanding Risk (UR) community was born in 2010 out of the recognition that disaster risk assessment and identification are activities that cut across sectors and industries. What began with just five founding partners has grown into a community of over 6,500 experts and practitioners. 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, nongovernmental, and financial sectors. Every iteration of the UR Forum has produced new ideas and partnerships that have improved risk assessments and helped to integrate them into policy and development planning. UR2016, "Building Evidence for Action," was held in Venice, Italy, from May 16 to May 20, 2016.

With financial support from

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GFDRR
Global Facility for Disaster Reduction and Recovery

WORLD BANK GROUP

G20 ERN international

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CIMA Research Foundation
OBSERVE TO PREDICT, PREDICT TO PREVENT.

Nephila

RMSI

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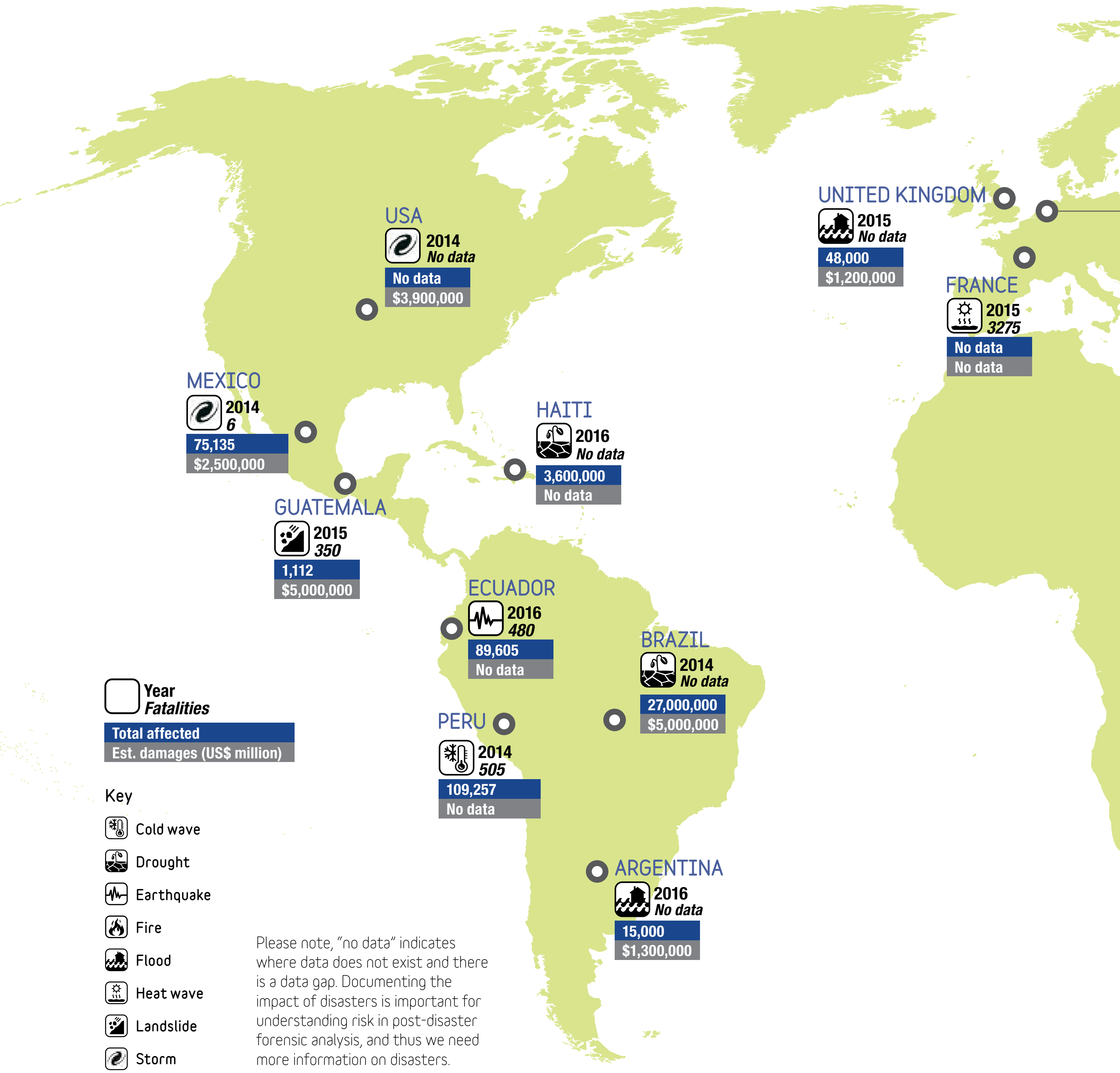
Major Disasters Since UR2014



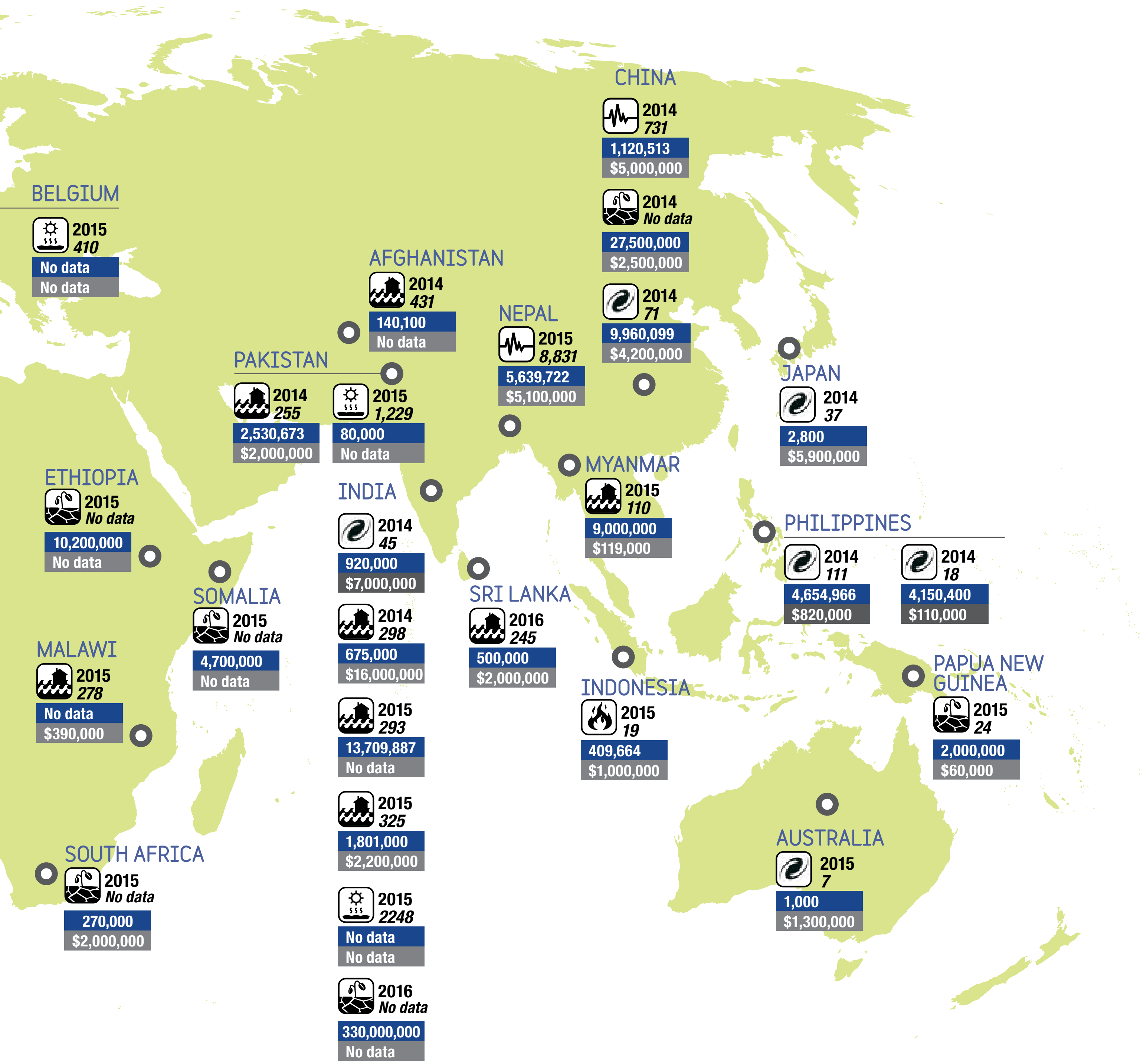
Year
Fatalities
Total affected
Est. damages (US$ million)

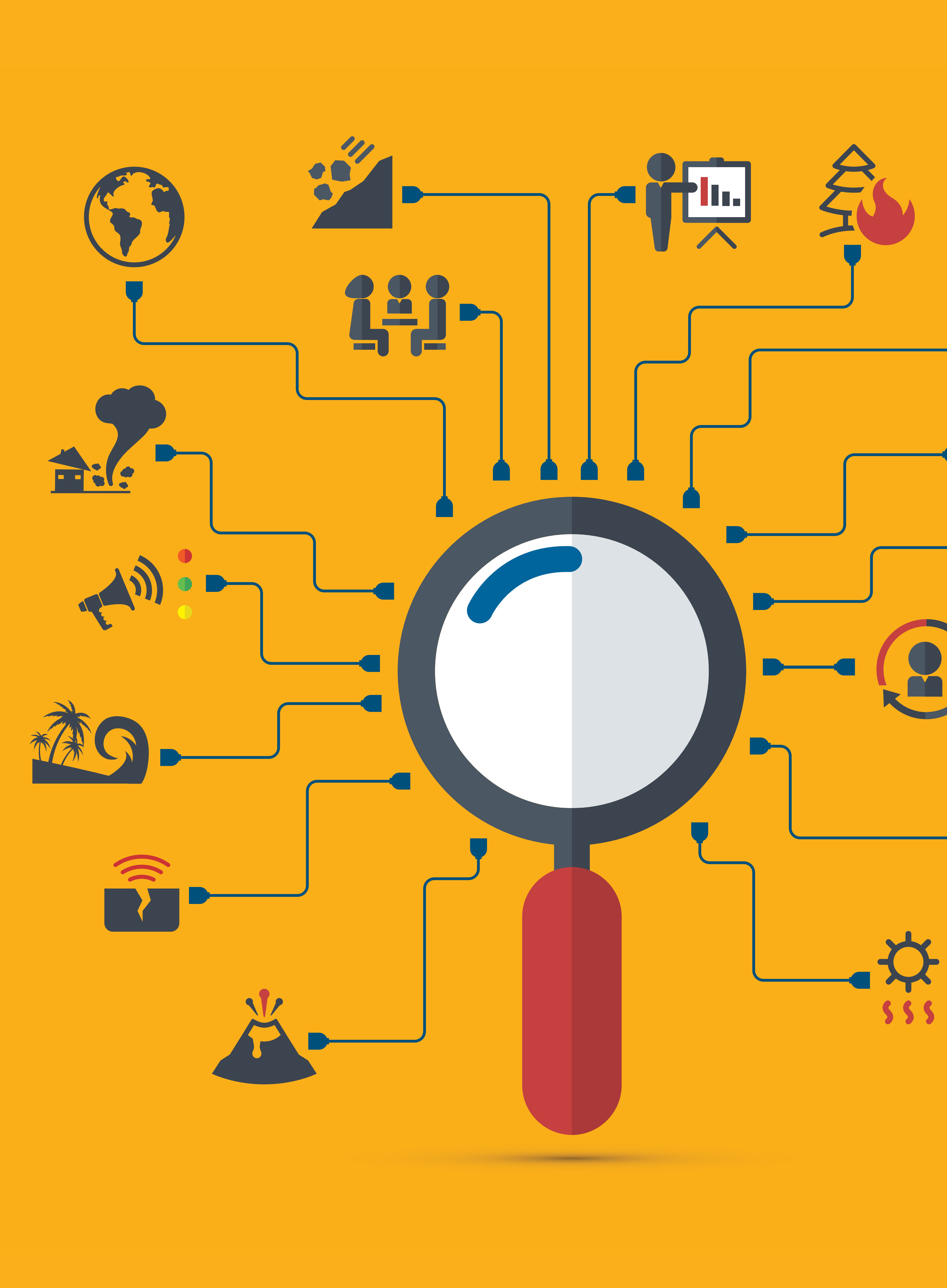
Key

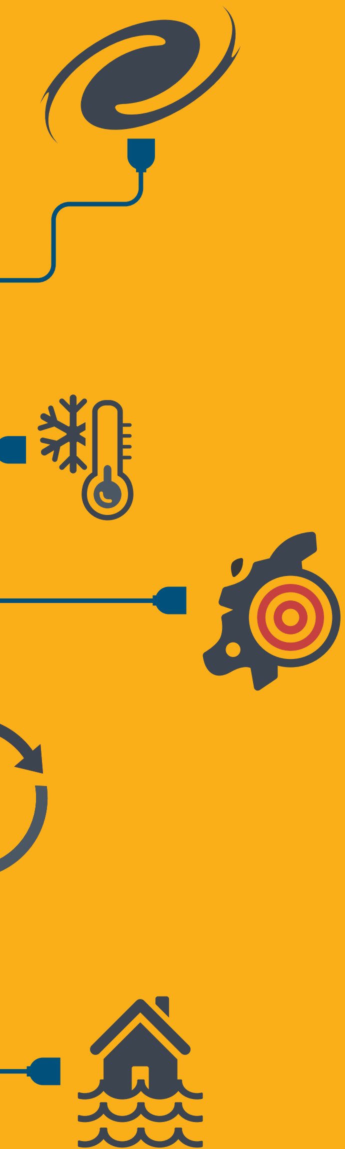
- Cold wave
- Drought
- Earthquake
- Fire
- Flood
- Heat wave
- Landslide
- Storm

Please note, "no data" indicates where data does not exist and there is a data gap. Documenting the impact of disasters is important for understanding risk in post-disaster forensic analysis, and thus we need more information on disasters.

Between the third UR Forum, held in late June-early July 2014, and the fourth UR forum in May 2016, the world has seen hundreds of disasters that have killed almost 50,000 people, affected over 550 million people, and caused more than $150 billion in mostly uninsured damages. Below are some of the largest disasters in terms of economic losses and human impact.







Connecting for Decision Making

"I Understand Risk, You Misunderstand Risk, S/he Fails to Act": Learning to Anticipate Behavioral Challenges in Predisaster Decision Making

Pablo Suarez, University College London

Introduction

Despite remarkable progress in our ability to model natural hazards, we continue to see too much inaction, or wrong action, in the field of disaster risk management—in areas ranging from individual reaction to forecasts to urban planning to global policy. Yet the community of practice that convenes at the Understanding Risk (UR) Forum, like most practitioners who aim to link knowledge with action, tends to embrace the "rational" model of decision making. This model entails a series of beliefs:

- We will maximize outcome of our choices.
- We always prefer "more" to "less."
- Our preferences are consistent.
- We want perfect information.
- We can do the math to find the best option, and will act accordingly.

In this framing, if we want to help people and organizations to understand and address risk, all we need to do is to share information and explain how different actions can lead to desirable outcomes. Of course, there is an inconsistency between the assumption of rational choice and the vastly suboptimal choices we see in the real world, as recent books—*Predictably Irrational* (Ariely 2008) and *Thinking Fast and Slow* (Kahneman 2011)—have shown. Unfortunately, the risk management sector still has a lot to learn.

During an intensely interactive 90-minute session held at the 2016 UR Forum, approaches and insights from decision science, behavioral economics, brain imaging, and other fields revealed some of the allegedly irrational choices made by those who manage risks, and suggested ways to use knowledge about predictable behavior in order to improve design and implementation of humanitarian and development work.

Predictable Failures to Understand and Address Risk: Experiencing Decision Errors

After hearing about the rational model of decision making, participants were invited to play "Storm Story," a short game on warnings and actions. Each team of roughly 10 players stood in a circle and confronted the risk of a storm that followed a set of simple rules:

- The storm grows in magnitude from 1 to 7. The number has to be stated loud and clear: the first player says "one," the next says "two," and so on. After number "seven," the storm loses its strength and becomes a magnitude "one," then starts growing again.

- When confronting a storm of category 1 to 6, a player has to invest in small protection by putting the right or left hand on the chest. When confronting a category 7 storm, a player has to invest in large protection by putting a hand on the head. The protection gesture has to be made while stating, immediately after the preceding player, the number corresponding to storm magnitude.
- The storm travels around the circle clockwise or counterclockwise depending on the preceding player's hand gesture for protection (left hand on chest or head pointing right means counterclockwise, right hand means clockwise).
- If players make a mistake—wrong number, wrong gesture, wrong time (too late, or out of place), or hesitation (doubt in number or gesture)—they must pay for the consequences of bad disaster management by walking around the circle behind other players while the game keeps going.

While frequent mistakes led to loud laughter and team bonding, participants experienced firsthand the extent to which the rational model fails to explain how people process information to make decisions: in the fiction of the game, the many mistakes meant failure to act correctly for disaster management—and this in a system whose rules were much simpler than those of the real world and whose consequences nowhere near as serious.

A short debrief examined the parallels between gameplay and real-world experience. Players learned about recent findings from neuroscience showing that different parts of the brain engage in decision-making processes in different circumstances, which leads to certain predictable problems in choice expression. The issue of geoengineering (a proposal to deliberately manipulate the global climate with sun-blocking particles injected in the upper atmosphere in order to reverse global warming) was introduced as an opportunity for reflecting on how assumptions of rationality may play out in related decision-making processes.

The Role of Framing in Choice Preference: From "the Allergic Snack" Question to Improv

For the next activity, participants were invited to examine the following scenario:

You will represent the views of the UR community in a televised debate about a proposed legislation that would lead to unacceptable levels of disaster risk. Your opponent is known for good debating skills. It is less known that this opponent has a mild, non-life-threatening food allergy that leads to profuse coughing, itching, and swelling of the face. During the pre-debate conversation with organizers, a waiter brings snacks. You happen to know that the food contains the allergen, and realize how helpful it would be for your cause if the opponent ate the food. . .

Half of participants received a yellow survey that asked the following question: *Do you pick up the tray and offer the snack to your opponent? (you know the offer will be accepted) A = Yes; B = No*

The other half of participants received a white survey that asked a related but different question: *Your opponent reaches out to the tray and takes a snack. Do you indicate that the food contains the allergen, and thus try to stop this? A = No; B = Yes*

According to classic economic theory, the only thing that matters in a person's choice is her preferences about the end state (would you rather have an opponent affected by allergy or not?). It shouldn't matter how the end state is reached. However, participants understood that framing a choice as action (yellow survey) versus framing it as omission (white survey) makes a difference. This is actually a *predictable* difference: people tend to favor omissions over commissions. These preferences, which behavioral scientists describe with terms such as "omission bias" and "status quo bias," play a substantial role in risk management; for example, they affect how forecasters communicate science-based predictions (see Suarez and Patt 2004).

Omission bias and status quo bias are noteworthy because they suggest that stakeholders will be reluctant to change decisions based on new information about future conditions of high disaster risk: people tend to stick to their original choice, whether it involves building in a coastal floodplain when seas are rising, or staying home when a hurricane warning calls for evacuation.

by Tint, McWaters, and van Driel (2015), risk managers can benefit from applied improvisation through increased authenticity and presence, improved ability to think on their feet, more-collaborative relationships, and greater creativity and innovation.

Despite remarkable progress in our ability to model natural hazards, we continue to see too much inaction, or wrong action, in the field of disaster risk management—in areas ranging from individual reaction to forecasts to urban planning to global policy.

risks. A modified version of the "Monty Hall" game demonstrated this reluctance: The facilitator showed four cards (an ace and three queens), shuffled them, placed them face down, and invited a player to guess which was the ace (the winning card). Before turning the chosen card, however, the facilitator turned up two of the other three cards and showed them to be queens (losing cards). This left two cards face down—the card that the player had indicated, and one remaining card. The facilitator then gave the player the choice to stay with her original pick, or to switch to the other remaining card.

Most players prefer to stick to the original choice, even when told by an advisor that switching cards greatly improves the chances of winning.[1] The situation is analogous to instances where scientists share forecasts about likely

Session participants also learned about gender dimensions of status quo bias: experimental evidence reported by Patt, Daze, and Suarez (2009) shows not only that some men were unlikely to change their choice, but also that they were even more likely to stick to their original choice when an advisor suggested that they switch cards.

A final activity drew from the improvisation talents of singer Bobby McFerrin and the control-autonomy-cooperation triad presented by Keidel (1995) in his book on organizational design. Participants first played a short game on framings for interaction ("No," "Yes, but. . ." and "Yes, and. . ."), then reflected on a video of a brief improvisational musical performance.[2] This exercise enabled participants to experience and appreciate the value of applied improvisation, a field that offers individuals the skills, methods, and mind-set they need to feel comfortable and connected in the face of the unknown. As argued

Conclusions and Recommendations: Choice "Anomalies" Happen, and Process Matters

All these activities immersed session participants in experiences that highlighted the contrast between observed behavior and predictions from the rational choice theory of decision making. Several key concepts and lessons emerged from these activities:

- *Bounded rationality.* In decision making, the rationality of individuals is *limited* by the finite amount of time they have to make decisions, the cognitive limitations of their minds, and the information they have.
- *Satisficing.* Instead of optimizing all the time, people tend to "satisfice"—that is, define a lower limit of acceptability for the outcome, and adopt an available option that is considered good enough.
- *Prospect theory.* Our estimation of probabilities is often very unreliable. Changes in perspective may change the

1 The mathematics of the game are surprising: switching cards will generate a winning outcome with a probability of 3 in 4, while staying with the original pick will win only one-fourth of the time. This is counterintuitive to most people, and indeed most people stayed with their original choice, and lost.

2 "Bobby McFerrin Demonstrates the Power of the Pentatonic Scale," July 23, 2009, https://www.youtube.com/watch?v=ne6tB2KiZuk.

relative desirability of options, so that framing can influence choice. Decision-making errors should be not only expected, but also predicted.

In the same way that hydrology shows us predictable patterns in flooding, decision science shows us predictable patterns in human behavior, and helps us understand how and why people make decisions the way they do. Insight into these patterns is of great significance to disaster risk reduction and other humanitarian and development work.

References and Further Resources

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Participants get a taste of what's to come in this interactive session during Pablo Suarez's Ignite talk on May 18.
Photo credit: Emanuele Basso.

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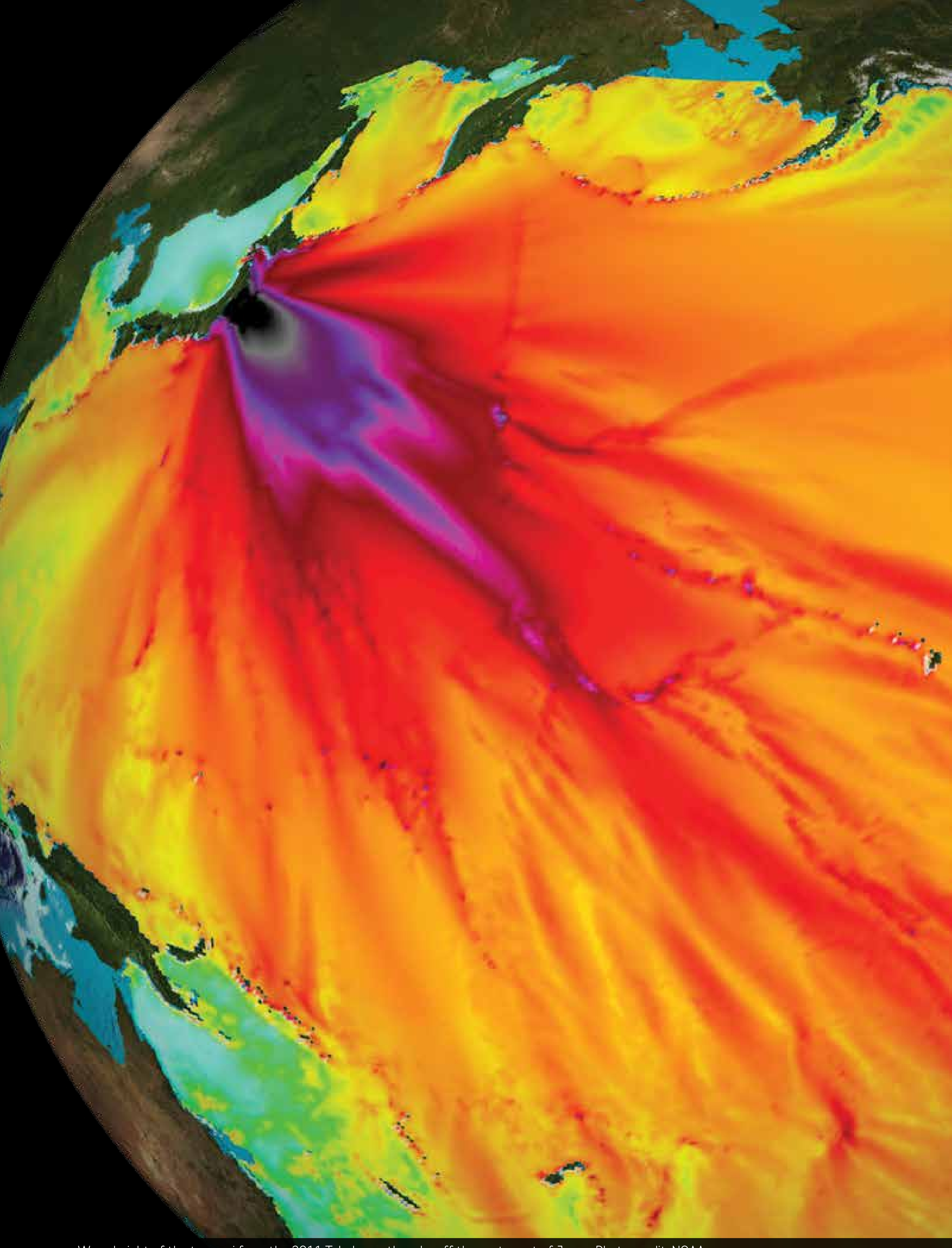


Wave height of the tsunami from the 2011 Tohoku earthquake off the east coast of Japan. Photo credit: NOAA.

The Final Mile: Connecting an Impact-Based Warning Service to Decision Making

Lydia Cumiskey, Deltares
Paul Davies, Met Office, UK
Nyree Pinder, Met Office, UK
Richard Murnane, Global Facility for Disaster Reduction and Recovery

Introduction

Despite huge advances in forecasting, climate science, and technology, it remains a challenge to present early warnings in a user-friendly way that initiates protective actions. One approach to meeting this challenge is impact-based forecasting, which seeks to improve end-user's decision making and prompt action by providing information on the potential impacts of hazard events. This approach involves mainstreaming the use of exposure and vulnerability information in forecasts, a step that presents its own challenges. The discussion below looks at how applying science to decision making, building sustainable multisectoral partnerships, and enabling effective coordination and response can all contribute to successful impact-based forecasting.

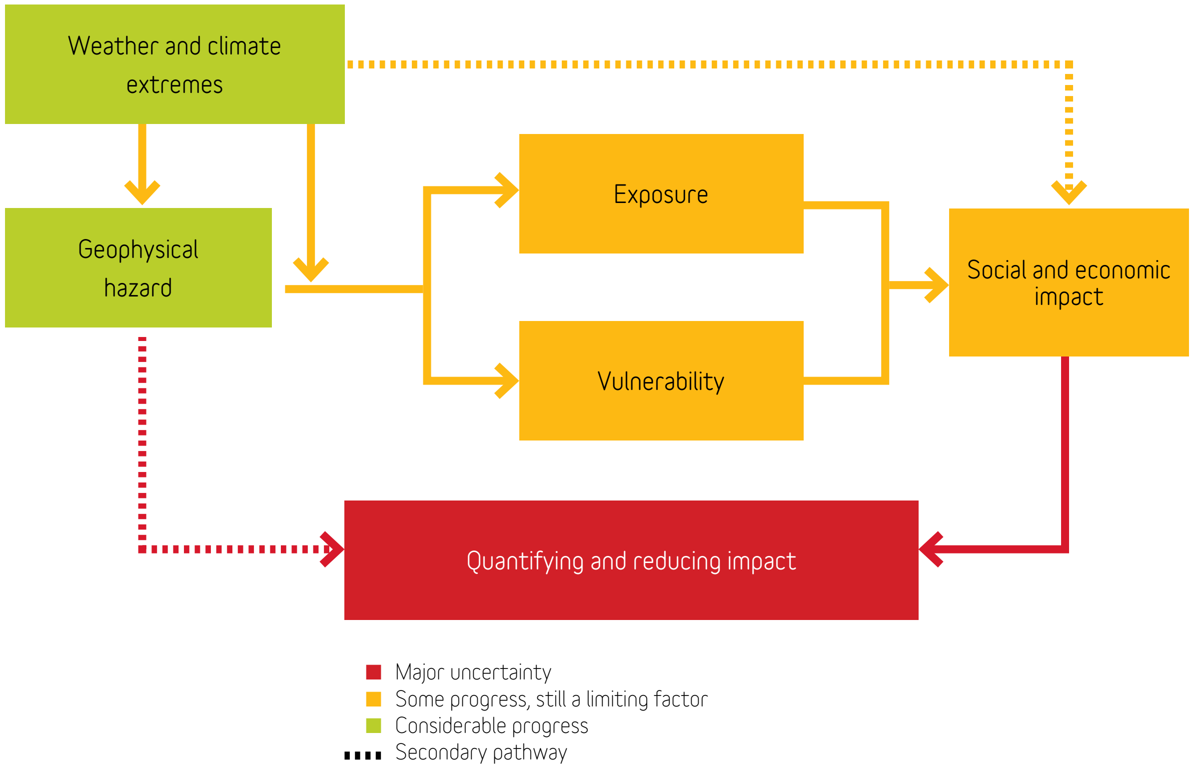
Background and Concepts

Generating Useful Science

Effective warnings require good science both for predicting hazards and for estimating the associated impacts. The impacts (e.g., on the public and various sectors) can be understood by having forecasters work with sector representatives. Practically this means making collaborative decisions to set thresholds for appropriate actions based on the expected impacts, with thresholds defined in terms of certain hazard parameters such as expected flood depths. The probability of exceeding these thresholds needs to be accurately forecasted with sufficient lead times. Clearly communicating the forecast's uncertainty is also essential. This not only allows users to make decisions in line with the reliability of the forecast, but it also helps to manage users' expectations about forecasting accuracy. This, in turn, enables those delivering the warnings to build trust with their users and ensure action is taken when needed.

The World Meteorological Organization (WMO 2015a) has a useful graphic showing how the components of an impact-based forecast system relate to one another and illustrating three different ways for estimating a hydrometeorological hazard's impact (figure 1). The traditional approach (red arrows) relates the magnitude of the likely impact directly to the magnitude of the hazard; it can contribute to risk identification and reduction, but accounts only for the magnitude of the hazard itself, not the relevant exposure or vulnerability. A second modeling approach (solid arrows) explicitly calculates each element

Figure 1. Relationship between the different elements of an impact forecast system.



Source: WMO 2015a.

and so requires detailed data on vulnerability and exposure (possibly available only from other agencies). A third and more subjective approach (dotted orange arrow) collects qualitative information from experts and estimates impact directly from the magnitude of the hazard.

Building Partnerships

Multisectoral partnerships are needed to support an impact-based warning service. National hydrometeorological agencies have expertise in weather and climate science, but they need to partner with experts in risk and disaster response, including disaster management and other government agencies, scientific institutions, international bodies, and local communities.

The WMO works closely with the Met Office UK, Deltares, and other expert agencies to support countries in establishing partnerships for impact-based forecasting development and in creating the relevant legal frameworks, memorandums of understanding (MoUs), standard operating procedures (SOPs), and communications strategies. See the WMO (2012) guidelines for more information.

Promoting Effective Coordination and Response

SOPs outlining the different roles and responsibilities of the hydrometeorological agencies and other actors will encourage a coordinated process and ensure there is one authoritative voice for warning dissemination. Contingency planning before the event will ensure that shelters are available and are built in safe places. Warning recipients need to learn how to interpret and use warning information to respond effectively, and should also be trained in how warning information relates to the expected impacts on daily priorities such as health and nutrition.

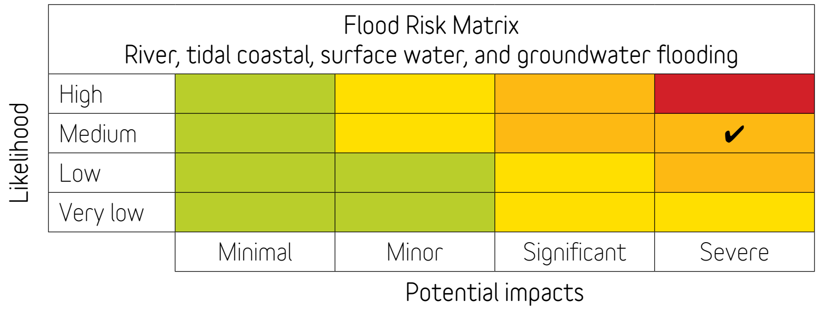
Case Studies

United Kingdom

Given the interdependency of natural hazards and the limitations of a segmented approach to hazard management, countries have begun to seek a unified approach to providing and developing forecasting and warning services. In the United Kingdom, the establishment of the Flood Forecasting Centre, a joint Met Office–Environment Agency initiative, is an important first step in providing joint scientific advice for flood-related, impact-based services and risk-based warnings to government and emergency responders. The center has built a cross-trained cohort of hydrometeorologists to facilitate better emergency planning and resourcing decisions. One of its services, the Flood Guidance Statement, presents an overview of flood risk for England and Wales, for all types of flooding, across five days, and it assesses the level of risk based on a likelihood and impacts matrix (see figure 2). The matrix definitions align to the severe weather warnings issued by the Met Office, which ensures a common picture and understanding of the developing weather-flood risk.

Another UK joint project that reflects the importance of partnerships for impact-based forecasting is the Natural Hazards Partnership, which is led by the Met Office and supported by the Cabinet Office Civil Contingency Secretariat and other agencies. The Natural Hazards Partnership's collaborative environment enables the development of innovative products and services that will provide governments and communities across the United Kingdom with better coordinated and more coherent assessments, research, and advice.

Figure 2. An impact matrix through which impact-based warnings can be developed.



Source: Met Office UK.

The Philippines

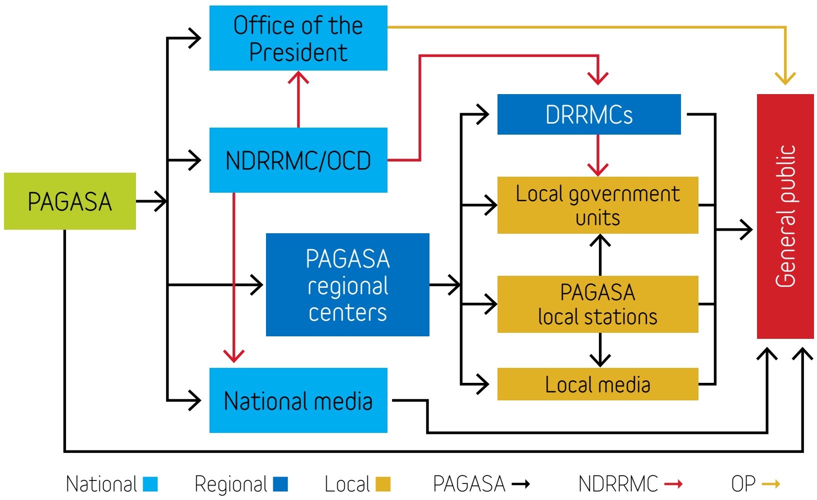
The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) produces and disseminates official coastal warnings in the Philippines. As shown in figure 3, it works with other related organizations to issue information. PAGASA faces many technical challenges—not only in generating timely hazard-specific, area-focused, and impact-based warnings, but also in communicating uncertainties and prompting effective responses. For example, it accurately forecasted the extremely high storm surge (7 m) during Typhoon Haiyan, but the forecast area was generalized, and the wave heights, inundation areas, and impacts were not included in the forecast. Moreover, although the lead times were sufficient for people to evacuate, many misunderstood the meaning of a storm surge and waited too long before evacuating; among those who did evacuate, many died because evacuation centers were built in unsafe areas. Finally, the messages sent to decision makers and the public were potentially confusing, as they included both color codes and a number scale to describe the storm's severity.

PAGASA, with partners, has conducted workshops with government agencies and the public so as to better understand their service requirements and the impact of severe weather on specific regions. For example, in its work with the Metropolitan Manila Development Authority, which manages Manila's transport network, PAGASA has gained information on the tipping points for severe transport disruption based on the volume of rain for a specific time period. With this information, PAGASA can now tailor bulletins to specific agency requirements in comprehensible language—an approach that prompts faster and more effective preparation and response following a severe weather forecast. PAGASA is now extending these tailored services to the other key sectors and continues to work to streamline its messaging (focusing on color-coded warnings that are clearly understood by users).

Mozambique

Weather forecasters in Mozambique face technical and institutional challenges. In order to move toward impact-based forecasting, they need high-resolution models and equipment, the ability to incorporate hydrological and inundation forecasting, and partnerships at the national, regional, and global levels. The WMO is promoting the necessary partnership by supporting Mozambique's efforts to establish an MOU among the national meteorological agency, the hydrological services, and the disaster risk management agency, and by taking the next steps to operationalize the partnership.

Figure 3. Warning and forecast information dissemination flow in the Philippines.



Source: PAGASA.

Note: NDRRMC = National Disaster Risk Reduction and Management Council; OCD = Office of Civil Defence; DRRMCs = Disaster Risk Reduction and Management Councils; OP = Office of the President.

Other forecasting challenges in Mozambique are being addressed with the support of the Red Cross. Efforts are being made to use multiple dissemination channels (e.g., social media, print, TV, and radio) to reach those living in the most remote areas. Under a forecast-based financing framework, the Mozambique Red Cross, German Red Cross, and Red Cross Red Crescent Climate Centre are working with hydrometeorological agencies and Mozambique's disaster risk management agency to strengthen the early warning–early action agenda. Moreover, to improve the capacity to prepare for tropical cyclones and floods in a timely way, a detailed analysis of forecast, exposure, vulnerability, and early actions has been conducted; the specific goal is to determine the critical point at which a forecast-based financing mechanism could be triggered to allow disaster risk managers and communities to act effectively before a potential disaster.

Jakarta, Indonesia

Jakarta's Disaster Information Management System hosts a number of innovative systems, and disseminates warnings via SMS, social media, websites and online maps, and sirens. But generating

Mozambique: Water level gauge (left); and WMO workshop on impact-based forecasting (right).
Source: German Red Cross/Mozambique Red Cross; Forecast-Based Financing Mozambique.

useful scientific information remains a challenge for Jakarta. Updating of sectoral and thematic data is slow and complex, and accurate real-time information on the duration and intensity of events is insufficient. However, the use of satellite, weather radar, and sensor data offers opportunities for timely validation. Crowdsourcing, which currently supports the Peta Jakarta open source flood map (figure 4), could be further exploited to collect other useful information; this approach would require engaging with citizens in a lengthy learning process, but could also offer new opportunities such as collaborative mapping of response actions.

Figure 4. Peta Jakarta interface.

Source: Peta Jakarta, https://petajakarta.org/banjir/en/.

Challenges

Impact-based forecasting that supports decision making faces several key challenges:

- *Communication.* Nationally and regionally, the lack of uniformity in forecasting (varying lead times, levels of accuracy, certainty, and geographic scales) makes it difficult to identify the right level of detail for communicating information.
- *Partnerships.* Building the partnerships needed to bridge the scientific and user communities takes time and resources; new partnerships will struggle to secure support unless the public and government feel the effort has value. Partners may also struggle to collaborate effectively if exchange of data between government agencies requires legal documentation, or if partnering agencies are unevenly funded. An additional challenge is the lack of a global mechanism that allows early warning providers and users to collate, share, and generate knowledge, and the lack of a forum for joint efforts to increase availability of and access to multihazard early warning systems by 2030 (a stated goal under Target G of the Sendai Framework for Disaster Risk Reduction).
- *Community participation.* Local communities can play a significant role in collecting real-time data and verifying results. This participation helps build trust in the forecasts and improves a community's response to warnings. However, fostering such participation requires a long-term commitment on the part of government agencies, both to supporting contributors and to using the community's contributions.

Conclusions and Recommendations

To support the development of impact-based warning services, countries should

- Increase scientific knowledge of hazards and impacts

- Invest in sustainable partnerships between hydrometeorological, disaster management, and other government agencies
- Develop SOPs for effective coordination and response
- Build societal awareness so that warnings are understood
- Engage communities in warning design and data collection, and continuously build their capacity to respond to warnings

On a broader scale, a community of practice on impact-based forecasts and warning is needed to bring together practitioners and scientists globally to exchange knowledge and share lessons.

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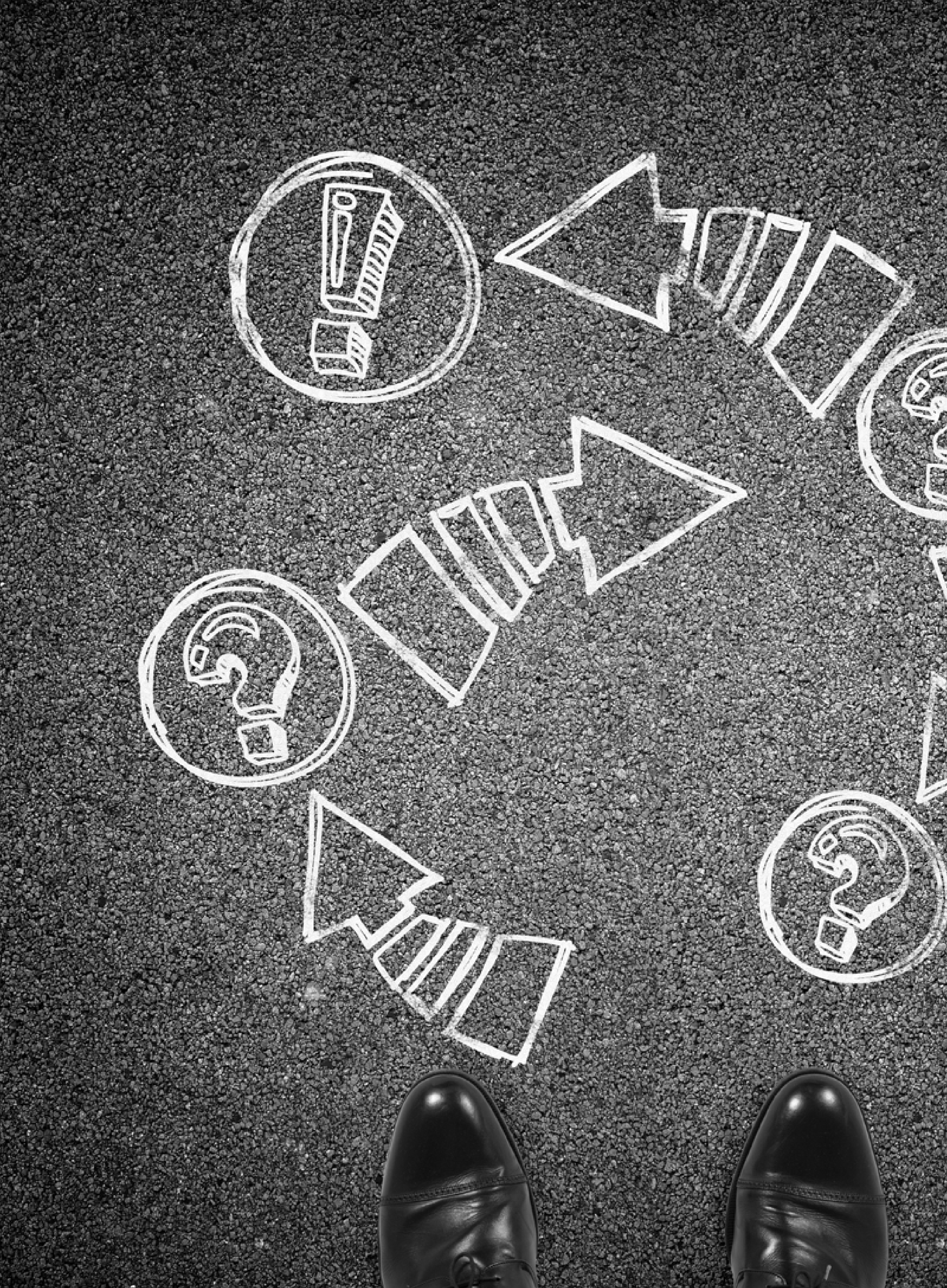
Participants engage in a discussion during the main conference. Photo credit: Emanuele Basso.

Adam Smith International | Adaptation Climate Change for Coastal Zone | Addis Ababa University | AG Europe | Agriculture Sector Development Unit | AIC | AIESEC Nigeria | AIR Worldwide | Aix-Marseille University | Allianz | Altamira Information | Altamira Information | Ambiental | Applied Hydro Solutions | Aqualogic Consulting | Arab Urban Development Institute | ARGANS Ltd. Armada Ltd. | Arup International Development | Asian Development Bank | Asian Disaster Preparedness Center | Athena Global AU-ECOSOC, African Union Nigeria Home Office Abuja | Australian National University | Autorité de contrôle des assurances et de la prévoyance sociale | BBC Media Action | Blue Nile National Institute for Communicable Diseases | Bogazici University | Boston University | BRGM | British Geological Survey | Bureau Haus Ltd. | Canadian Space Agency | Çankırı Afet ve Acil Durum Müdürlüğü CARD Consult (P) Ltd | CEFDHAC | Cellule de Prévention et Gestion des Urgences | Center for Management Technologies of Yerevan | Center for Rural Development and Planning | Center for the Promotion of Science and Technology | Central European University | Centre for Disaster Mitigation and Management, VIT University | Centre for Disaster Risk and Crisis Reduction Centre National de l'Information Géo-Spatiale (CNIGS) | Centro Euro-Mediterraneo sui Cambiamenti Climatici | Christian Aid | CIMA Research Foundation | Cities Alliance | Climate Change Network Nigeria | Climate Decision | Climate Policy Initiative | Climate Resilience Improvement Project-Ministry of Irrigation & Water Resources Management | Climate Wednesday | Collaborating Centre for Oxford University and CUHK for Disaster and Medical Humanitarian Response (CCOUC) | Comité Interministériel d'Aménagement du Territoire | Coordination of Afghan Relief - CoAR | Council for Geoscience | Coventry University | Daily Impact Emergency Management | Dalit Empowerment Center (DEC) | Dalit NGO Federation (DNF) | Dalit Welfare Association (DWA) Danish Red Cross | Deltares | Department of Education, The Philippines | Department of Foreign Affairs and Trade, Australia Department of Irrigation, Sri Lanka | Department of National Planning, Sri Lanka | Department of Planning and National Development, St. Lucia | Department of Surveys, Malawi | Desh Seba Sangstha | Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH | Diakonie Katastrophenhilfe (DKH) | Direction de Protection Civile, Haiti | Disaster Management, Maldives | Disaster Management and Finance, India | Disaster Reduction Nepal (DRN) | Divergent Group | DMInnovation | Dreams From the Slum | DRR Dynamics | EAE School | Earth Observatory of Singapore | Economic Community of Central Africa States (ECCAS) | Economic Community of West Africa State, Commission, ECOWAS Commission Ecorys Research and Consulting | Environment Agency Austria | ERN Evaluación de Riesgos Naturales | ERRA | Ethiopian Development Research Institute (EDRI) | Ethiopian Ministry of Environment, Forest and Climate Change | Ethiopian Red Cross Society | Euro-Mediterranean Centre on Climate Change | European Academy of Bozen/Bolzan (EURAC) | European Commission, Joint Research Centre | European Space Agency | eWASH Initiative EY | Federal Capital Territory, Abuja | Federal Department of Foreign Affairs, Switzerland | Federation of Youth Clubs (FYC) Floodtags | FMGlobal | Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) | Fondazione Edmund Mach Fondazione Eni Enrico Mattei | Food and Agriculture Organization (FAO) | Food for the Hungry | Fraunhofer-Institut für Offene Kommunikationssysteme FOKUS | Freie Universität Berlin, interdisciplinary security research | Hans Ertel Centre for Weather Research (DWD) | Fujitsu Labs of Europe Ltd Fundación Guatemala Gambia Red Cross Society | GCC Emergency Management Centre | GEADIRR | GEM Foundation | General Direction of Civil Security | Geo Enviro Omega | GeoAdaptive LLC | Georgian Association for Protection of Natural and Energy Resources | GeoVille Information Systems | German Aerospace Center (DLR) German Red Cross | Giving Garage | Global Alliance of Disaster Research Institute(GADRI) | Disaster Prevention Research Institute, Kyoto University | Global Facility for Disaster Reduction and Recovery (GFDRR), World Bank Group | Global Volcano Model | GNS



When Uncertainty Is Certain: Tools for Improved Decision Making for Weather and Climate

Pete Epanchin, Global Climate Change Office, U.S. Agency for International Development (USAID)

Background and Concepts

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. It would be dangerously foolish to try to sell climate services, or the development and provision of weather and climate information for decision making, as a simple solution to this challenging problem of uncertainty. But when developed well, climate services can help provide a solution to building resilience to weather and climate variabilities.

Climate services are sometimes viewed as a linear process that starts with observation and data collection, followed by data curation, processing, and analysis. Analyses must be interpreted and tailored to end-users (whether the general public or specific sectoral users), and finally disseminated and adopted by those users, who can then manage risk by taking action based on the information provided. But while it may be easiest to comprehend this information flow as a linear chain, in reality it is a complex, webbed network that requires coordination and collaboration across many organizations and interests.

At the 2016 Understanding Risk Forum, our panel and audience reflected components of the needed organizational diversity associated with the pathway of a successful climate service, from creation, to delivery, to use.[1] In

[1] At the start of this session, Julie Arrighi (American Red Cross; Red Cross Red Crescent Climate Centre) led an activity in which audience members self-sorted along two axes: where they most closely identified in the climate services value chain, from climate information and data providers to communicators of action-oriented information; and the frequency with which they engaged in work related to climate services. The audience was fairly evenly distributed across both axes.

addition, the panel reflected the application of climate services across a wide range of time scales, from early warning systems to 10-day and subseasonal outlooks, to seasonal and multiseason forecasts, to predictions that span multiple decades.

For a climate service to be used and valuable, such that it results in an end-user's positive behavioral response, the provider of that service needs to first understand the problem that the user faces. While providing climate services might seem like a great way to build a community's resilience to climate change, we should beware of solutions in search of problems and not make assumptions about the problem.

While providing climate services might seem like a great way to build a community's resilience to climate change, we should beware of solutions in search of problems and not make assumptions about the problem.

Case Studies

Meeting Farmers' Needs

Research by Amy Barthorpe and Ben Lloyd Hughes points to a novel method of understanding the needs of end-users. By exploring data posted via SMS text messaging on WeFarm, a farmer-to-farmer information sharing network, it is possible to take an incredibly rapid, virtual pulse check of the farmers and their real-time, real-world issues, including concerns about precipitation patterns and water availability. These posts give immediate insight into farmers' needs and can then point to opportunities that a tailored climate service could take advantage of for those farmers. This type of analysis can also be used as a rapid assessment of an existing climate service's effectiveness, specifically by providing feedback that can be used to improve that climate service.

Consulting with Stakeholders

Pete Epanchin highlighted several USAID activities in climate services, including the Climate Services for Resilient Development partnership. In developing and providing climate services, this partnership first consults with local stakeholders and end-users to understand the problem as it is perceived by the users, and then identifies opportunities for cocreating a demand-driven climate service solution. For example, in Colombia, the partnership engaged in conversations with over 175 stakeholders (including government agencies, academics, farmer cooperatives, civil society organizations, and the private sector) in order to understand the landscape of existing climate services and their use, to identify priority needs, and to determine gaps in decision support that could be filled by a climate service. In Colombia and other countries where this model has been implemented, action is being taken in the design and scaling of climate services.

Responding to Forecasts

The complexity of climate services and how climate data are best used was addressed by Andrew Kruczkiewicz, who pointed out that a good forecast may have no value if end-users aren't able to respond with appropriate actions. This admission raises a question, one that links data, time scales, and action: what should come first, the forecast or the action? In other words, is it better to start with a forecast and hope it will trigger an appropriate response, or to prepare an appropriate response that anticipates a forecast? While there may not be a single right answer, this question has inspired the field of forecast-based financing. Under this approach, when a forecast hits a certain likelihood threshold for an event, say flooding, then a set of predetermined actions must be taken immediately, in advance of the flood. In order for this approach to work, the time needed to complete the action must be accurately paired with the lead time for the forecasted hazard. If the action is fortifying housing infrastructure against floods, and this action takes six months to complete, then it would be appropriate only when the seasonal forecast indicates at least a six-month window of no flood risk. But actions can also be taken on shorter time scales: in Peru, for example, a six-day flood forecast was sufficient to mobilize the procurement and distribution of hygiene kits in advance of the flood event. Having "no regrets" plans of action in place can add value to a forecast and can reduce uncertainty in the process of translating a forecast into action.

Improving Decision-Making Capacity

Enrico Ponte presented work covering the much longer time scales useful for planning and for increasing preparedness, whether at the individual, community, or national level. Decision-making capacity can be improved by using an interdisciplinary, risk-assessment approach—one that synthesizes long-term climate projections and other data sets, both qualitative and quantitative, to develop risk profiles and sectoral vulnerability analyses that are used to understand and manage risk. This approach was used in planning for the present and future of San Jose, Costa Rica. It included a multihazard probability assessment model integrated with projected scenarios of future climate change and urban growth, and a participatory social vulnerability assessment. This approach informed relevant decision makers about future risks and about ways to mainstream risk management under responses that could be made now or in the future.

Conclusions

Integrating weather and climate data into decision making helps us prepare for and minimize the impacts of natural hazards, including climate variability and change. There is a complex network underlying a climate service; each entity provides an important contribution. No one single organization can deliver all of the elements needed to support a climate service's successful results. As the field of climate information services grows, there is much that we can learn from each other in order to create and promote sustainable information systems rooted in evidence-based best practices. By collaborating with the network of climate service stakeholders, we can cocreate solutions that build climate resilience.

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A full house marks the beginning of UR2016 opening ceremony. Photo credit: Emanuele Basso.

Communicating for Action: What's Needed?

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Shared Approaches to Developing Risk Information

Effective communication underpins risk and resilience. It influences how experts develop and share data, how professional users understand the data and make decisions based on it, and how ordinary people take actions to reduce risk in their everyday lives.[1]

Developing risk information requires new types of partnerships between organizations that often have only a limited understanding of one another's approaches and value systems. It can involve knowledge exchange among national and international scientists, private sector actors, humanitarian and development organizations, community groups, and social networks (Visman 2014). For example, the Zaman Lebidi project in Burkina Faso brings together climate scientists, meteorologists, social scientists, development and communications practitioners, and agro-pastoralists to co-produce decision-relevant climate information (see box 1). Developing effective risk communication has specific implications and requirements for each type of actor.

The *providers of risk information* need (1) a clear mandate that requires them to make relevant risk information available, (2) the capacities to effectively communicate risk, and (3) the willingness to recognize others' risk knowledge systems. Rarely is risk communication an integral part of scientific training, yet the consequences of miscommunication are potentially great—not only for those at risk, but also for those communicating risk. Following the 2009 earthquake in l'Aquila, Italy, for example, six earthquake scientists were convicted of manslaughter for playing down the risks to the public (Nosengo 2012).

Box 1: The Zaman Lebidi Project

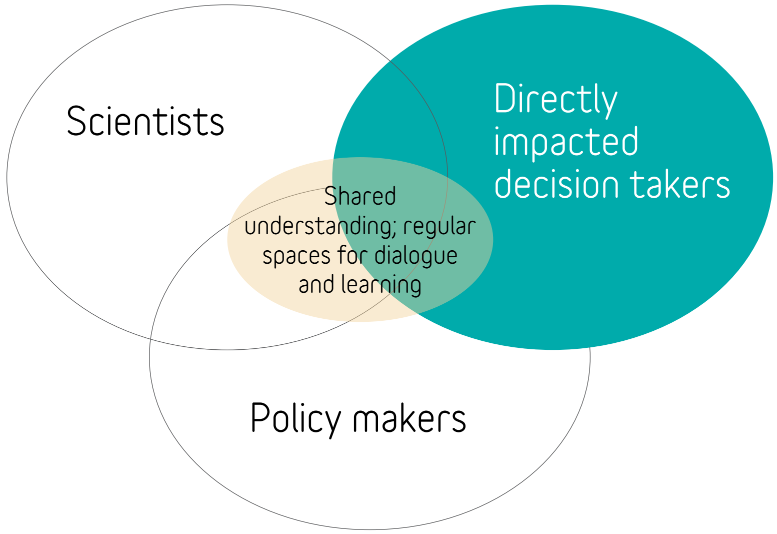
The Zaman Lebidi project in Burkina Faso is seeking to build the resilience of people to climate variability, extremes, and change by bringing together local populations, climate experts, and media and development practitioners to co-produce relevant climate information. Part of the project focuses on linking scientific data and traditional ways of understanding and using weather signals, with the aim of making weather and climate information more actionable, trustworthy, legitimate, understandable, relevant, and timely.

Sources: Rowling 2016; Christian Aid 2015.

Among the *users of risk information*—including both those people who are directly affected as well as the local, national, and international agencies seeking to support them—there is a huge need to improve scientific literacy

[1] E. Visman, R. Murphy, S. Evans, L. Pearson, and King's College London Humanitarian Futures Programme, "Dialogues for Disaster Anticipation and Resilience" (tumblr), http://dialoguesforresilience.tumblr.com/."

Figure 1. Different partners working to develop risk information have different priorities and few spaces for building collective understanding and sharing knowledge.



Source: Adapted from Kniveton 2014.

so they can better understand what information is available, what degree of certainty it holds, and how it can be appropriately used. Risk information alone is not enough: it needs to be accompanied by the resources and approaches to effectively use it.

Enablers—such as the World Meteorological Organization's Global Framework for Climate Services,[2] the United Nations Office for Disaster Risk Reduction (UNISDR), and the UNISDR disaster risk reduction (DRR) platforms—need to support the development of risk information frameworks that work across sectors, time frames, levels of decision making, and risk type. They need to ensure that national budgets support sustainable risk communication services and allow those directly affected a seat at the table where the risk research agenda is determined.

Given that actors such as scientists, policy makers, and decision makers are shaped by differing priorities, it is important to ensure that efforts to strengthen resilience benefit the people most directly at risk. Currently, there are few regular spaces where these actors can build joint understanding and where emerging learning can be shared (figure 1).

Stronger Information Ecosystems

Viewing information landscapes as ecosystems—as the international nongovernmental organization Internews does—makes clear that risk information is generated and shared in a complex and dynamic environment. When information flows through such dynamic systems, it is often transformed by those who can either validate and amplify it or (if it comes from certain actors and sources) disqualify it.

When Information Ecosystems Fail

Functional information ecosystems involve high production and circulation of risk information (Internews Center for Innovation and Learning 2015). Poorly functioning information ecosystems lack efficient and inclusive information flows.

The importance of a well-functioning information ecosystem can be seen by comparing government responses in Myanmar to two different cyclones. Before Cyclone Nargis in 2008, the government chose not to proactively circulate the information it had about the oncoming cyclone, and as a result communities were unprepared for an extreme weather event in which many thousands died. In 2015, however, during the worst flooding in a decade, the government regularly broadcast information about the risks of Cyclone Komen and explained how people could keep safe. This time there were fewer than 200 fatalities, and although the intensity of the event was less severe, the significantly lower death toll was due in no small measure to the improved flow of information.

2 See the video on how to communicate risk effectively at https://vimeo.com/170965566.

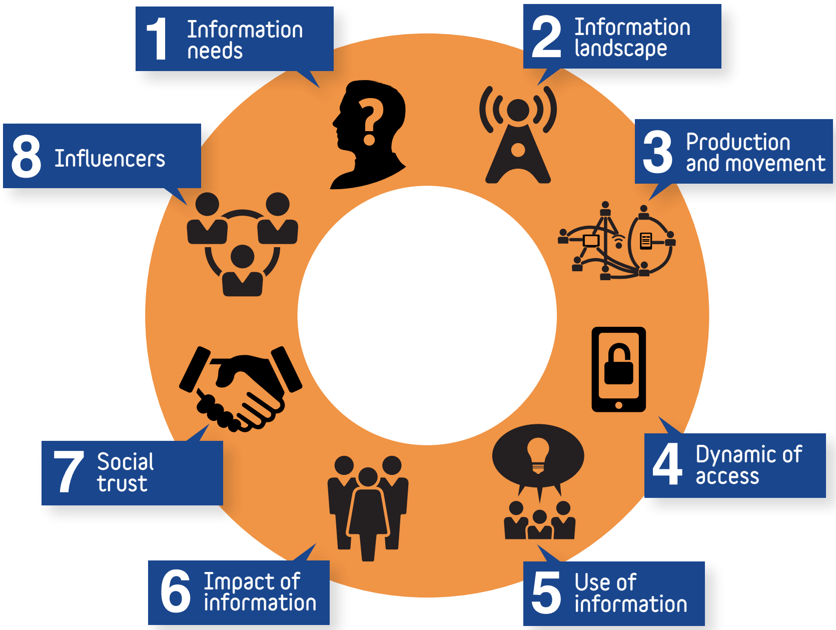
Mapping Information Ecosystems

Diagnosing information ecosystems and making corrections to how they function can improve information and reduce risk. Consider the experience of Jakarta, Indonesia, for example, in using a tool developed by Internews to map information ecosystems. The tool showed that there was no two-way flow of information between Indonesia's provincial disaster management authorities and the communities in Jakarta most prone to flooding; it also showed that some of the most marginal communities at risk did not consider intermediaries used by the city authorities entirely trustworthy or credible. Officials aimed to correct this by deploying crowdsourced flooding platforms that fed local incident information into the provincial disaster management authority control room and by identifying alternative influencers who had the trust of the most marginal communities.

Building Risk Literacy in Local Media

The capacity of local media outlets to create and distribute information is a critical determinant in how well information ecosystems function. Local media need to improve their risk literacy in order to help journalists understand how planning—both rural and urban—can create risk, how infrastructure can be impacted by extreme weather, and how legitimate political dynamics and dilemmas can come into play

Figure 2. Eight critical dimensions of information ecosystems.



Source: Internews Center for Innovation and Learning 2015 (http://www.internews.org/); licensed under a Creative Commons License, https://creativecommons.org/licenses/by-nc-sa/4.0/.

in investing in flood mitigation schemes. In Chenai, India, for example, it was only after the devastating 2015 floods that the Chennai-based national newspaper *The Hindu* investigated and reported on the possible role of the Chembarambakkam Reservoir in the flooding of the city, and suggested that better reservoir management might have made the flooding less severe. Greater investment in the risk literacy of journalists is one way to improve the accountability of city authorities to the communities they are protecting.

Dialogue with People at Risk

In the Philippines, a highly disaster-prone country, disaster risk is a part of life. The challenge is not necessarily to get vulnerable people to understand risk, but for different stakeholders to understand the underlying issues behind people's vulnerability. The discussion below describes how improved communication in the Philippines led to a better grasp of what makes certain communities especially vulnerable.

Understanding Risk through Their Eyes

In 2009, when Christian Aid wanted to conduct a DRR consultation after a big flood, some poor urban communities were largely resistant. Dialogue with these communities revealed the reason for their opposition: they feared there was a conspiracy to demolish their houses and relocate them to resettlement areas far away.

The urban poor were concerned for their livelihoods, which they would have to leave behind, and they foresaw having to return to the city or resorting to desperate activities such as illegal logging. People were also afraid of unknown risks. Many of the supposedly safer resettlement sites had undeveloped facilities and were prone to floods and landslides. The risk of fires—not only accidental fires but often deliberate fires designed to clear informal settlements—was also a concern.

Dialogue also revealed that residents tend not to build durable houses because eviction and demolition are so common. It showed further that for poor urban residents living in danger zones, where land rights are not protected, DRR becomes a threat, not a life-saving strategy.

Building Trust and Supporting Action

To build trust with these vulnerable groups in the Philippines and to better understand the context of their experience, community organizers lived among them. They mentored leaders and helped to form grassroots organizations, thus creating knowledge hubs and community structures for information flow. Leaders had dialogues with risk experts as legitimate and equal stakeholders. Residents were supported in developing their own community plans based on the issues and risks that had been identified in consultation with the experts. Some communities set up emergency response teams that were able to respond to various incidents quickly. Those who had accepted relocation used their risk knowledge and leadership skills to negotiate for safe and acceptable settlements.

Urban poor leaders living along canals in Manila meet with community organizers to address their concerns about land and housing security.

Source: Allan Vera.

These efforts to interact with the vulnerable, understand disaster risk from their eyes, and build trust led to the use of more effective DRR strategies. The importance of looking at risks not from the disaster perspective but from the perspective of underlying issues of poverty became a key lesson of the Linking Preparedness, Response and Resilience project.[3]

Effective Use of Media

Mass media can complement community dialogue by prompting conversations and reaching people at scale. To be effective, however, it must follow basic guidelines.

- *Know the target audience.* Media groups must understand who they are trying to communicate with and how to tailor their communication to different audiences. Demographic information can be a useful starting point, though it offers only a small part of the picture. Understanding the "psychographics" (i.e., beliefs, values, preferences) of target audiences will make it possible to connect with them more deeply. Understanding how different audiences use media is also necessary for reaching target groups effectively. Investing in audience research is therefore critical to deeply understanding target audiences and how to communicate with them.
- *Know what to change.* Once the audience is thoroughly

[3] Start Network, "Linking Preparedness, Response and Resilience in Emergency Contexts," http://www.startnetwork.org/start-engage/linking-preparedness-response-and-resilience-emergency-contexts.

understood, it is easier to consider what can feasibly be changed with mass media. Many media initiatives about DRR presume that people simply need information. Yet changing one's behavior often requires more than knowing what to do. It may require a shift in mind-set, or encouragement and support to take action. For example, when BBC Media Action conducted research in Bangladesh to understand people's perceptions of and reactions to climate change, it discovered that while some of the biggest challenges were community-wide, people were not taking collective action to deal with them (Al Mamun, Stoll, and Whitehead). In response, BBC Media Action launched a national television program called *Amrai Pari*, which was designed to motivate communities to work together to address common problems. After watching the program, 81.8 percent of viewers reported that their understanding of resilience issues had improved, and 36.5 percent reported that they had taken action to improve their resilience (BBC Media Action 2015).

- *Be engaging*. Media outputs for DRR must appeal to their audience, yet too often productions fall flat, contributing to the perception that risk reduction is either too scary to think about or too boring to deal with. Media offers tremendous opportunity to approach off-putting topics in fresh, novel ways. Investing in top-quality producers, scriptwriters, and talent is essential for ensuring that the output appeals to the audience.

Conclusion

Disaster risk specialists can improve the impact of their work by ensuring that information is developed through strong communication among different actors, by understanding the ecosystems in which information flows, and by using media effectively to prompt conversations and reach people at scale.

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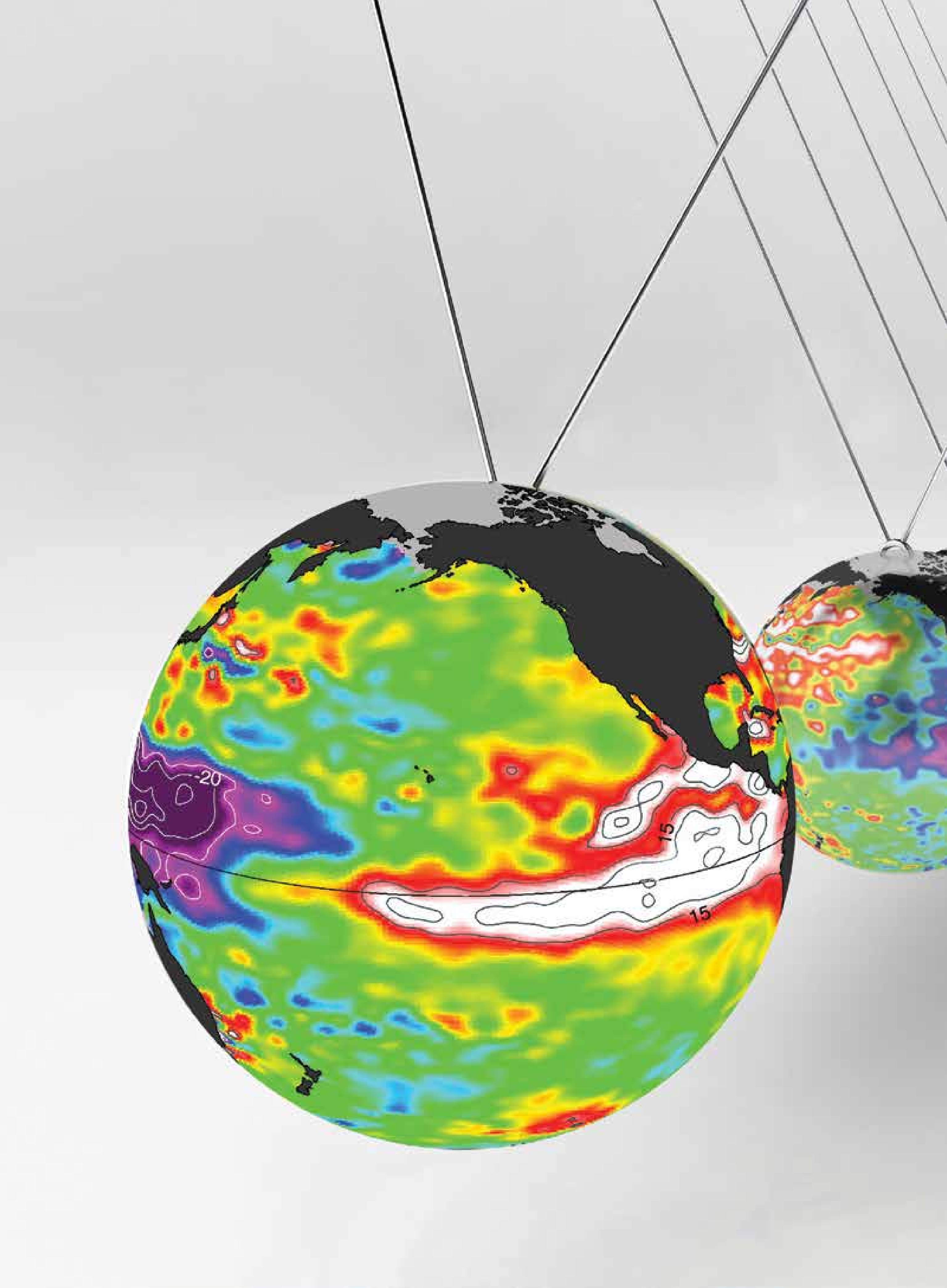
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MapSlam:
Revealing the Common Misperceptions about El Niño and La Niña

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Introduction

Does society really understand the risks and potential impacts associated with El Niño and La Niña? Are decision makers and risk managers leveraging the information that is available? Risks associated with long-term climate change are increasingly managed by risk managers, but is the same happening for risks associated with short- or medium-range modes of climate variability? Traditional approaches are driving efforts to answer these questions, but they are perhaps struggling to capture the full geophysical and socioeconomic complexities they confront. New interactive methods of addressing these questions are in development, including one, the MapSlam, that excites emotion, sparks creativity, and depends on confrontation.

Background

"ENSO" refers to the El Niño–Southern Oscillation, the interaction between the atmosphere and the equatorial Pacific Ocean that results in a somewhat periodic variation between below-normal and above-normal sea surface temperatures. El Niño is the name for periods of above-average sea surface temperatures in this region, and La Niña is the name for periods of below-average temperatures. The sea surface temperature variations initiate a domino-effect reaction through the atmosphere which, over time, travels around the globe. This domino effect is what leads to shifts in drier and wetter conditions in places significantly distant from the equatorial Pacific. The connections of global shifts in weather and climate driven by El Niño and La Niña are called teleconnections.

Just as forecasts are available for the potential development of El Niño and La Niña, seasonal and shorter-term forecasts are available to explore the impact of teleconnections. Through interactive tools, bulletins, and maps, physical and social scientists have taken steps to communicate shifts in risk and to inform risk managers both about impacts on weather and climate and about their level of confidence in the potential shifts. It would seem obvious that these tools have led to a deeper knowledge of risks associated with El Niño and La Niña, but there is growing evidence that gaps remain in leveraging the available information to assess and mitigate risk.

Climate researchers in the social and physical sciences have struggled to address these gaps in both academic and applied contexts. With many papers penned on relevant topics—from calculating forecast skill, to assessing methods of communicating uncertainty, to classifying styles of representing spatiotemporal impacts globally—there would perhaps seem to be a consensus on how to manage El Niño and La Niña risk. With each passing event, substantial progress is made with communities, organizations, and decision makers around the world, but stories still emerge that demonstrate lingering confusion about how to assess and interpret El Niño and La Niña information. As a potential event, such as the current possible La Niña, approaches, risk managers have an opportunity to use uncertain, yet potentially extremely valuable, pieces of climate information in their decision making. But instead of leading to improved decision making, the available climate information can lead to the perception of a wicked problem of climate information saturation—one that could drive risk managers to reject potentially valuable climate information as too complex and intrinsically uncertain and rely instead on simpler, potentially incorrect information. This failure to understand the value of the climate information available could lead to a failure to include the data, or worse, to use data incorrectly. Either error could potentially increase vulnerability to climate risk.

New Methods of Exploring Climate Risk

Linking users of climate information with developers of climate information will likely increase chances that the information is used correctly. Traditional methods succeed in communicating a portion of the climate risk to a subset of users, with an even smaller subset integrating risk information into their decision-making processes (and a smaller subset still doing so correctly and efficiently). Acknowledging the need to develop new ways to communicate climate risk, with an emphasis on affording a two-way conduit between user and developer and fostering emotive critical discussion, the MapSlam was conceived.

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MapSlam

The MapSlam is an interactive activity inspired by poetry slams, in which poets battle head to head in a structured event. In short (two- to five-minute) rounds, each competitor presents his or her piece and has an opportunity for rebuttal. The rebuttal portion is usually not planned, as the participants cannot be certain of the material that the opponent will present; this aspect of the competition demands acute improvisational skills from each. Like a poetry slam, a MapSlam involves a moderator to ensure that each side respects the agreed-upon rules of battle. The winner of the MapSlam is the person who has the most useful map in the context of representing and communicating El Niño and La Niña risk.

Two iterations of MapSlam were featured at the 2016 Understanding Risk Forum. First, map user was pitted against map developer in a four-round contest. Second, two map developers went head to head to debate the usefulness of their respective products.

MapSlam 1: Map Developer versus Map User

Lisa Goddard of the International Research Institute for Climate and Society (IRI) explains the advantages of IRI's El Niño maps. These maps feature teleconnections, or shifts in temperature and precipitation over certain areas of the globe during certain months, to convey how risk shifts during El Niño. Lisa goes on the offensive in noting how forecasts are more skillful during El Niño and La Niña, compared to a year with average conditions.

Julie Arrighi of the Red Cross fights back. She emphasizes the absence of data at the spatial resolution needed for community-based decision making, and reiterates the need for higher-resolution data. She jabs with concerns about the skill that went into making the maps, as many of her decisions impact livelihoods in low-income areas. She challenges her opponent: can these maps be used to justify shifts in funding?

Lisa battles back, explaining that the maps offer useful seasonal forecast information, but just how useful depends on the time scale of the decisions and size of the area to which they are applied. Referencing the Sahel situation, she states that on a regional scale, decisions may be shifted: when outcomes are averaged overall they will likely fall along the lines of the teleconnection, while at the community level they may not be even the same sign.

Momentarily pushed back against the ropes by Lisa's assertion of the map's value, Julie regains poise and explains part of the problem: action needs to be taken on a spatial scale, but the maps need to focus more on the temporal elements of the signal, as well as the magnitude. Does increased rainfall mean floods? Is there an equal chance of floods over the entire region?

MapSlam 2: Map Developer versus Map Developer

The second MapSlam event features a battle of El Niño and La Niña global streamflow maps, with Paul Block from the University of Wisconsin facing off against Philip Ward of VU University Amsterdam. To moderate this sure-to-be-rambunctious event, Pietro Ceccato of IRI steps into the ring to maintain order and ask the tough questions. For this event, the audience was asked to take the role of users, tasked with voting for which map better informed decision makers of shifts in flood risk during El Niño.

Paul started out steady, scrutinizing Philip's map like a synthetic aperture radar sensor collecting a backscatter of data in order to build his case. But instead of denouncing Philip's map, he starts out by praising his own, particularly the easy-to-understand categorical probability of parameters that inform users if they can expect normal, below normal, or above normal streamflow during El Niño events. Further, his maps capture predictive capabilities at fairly high resolution, which may be useful for subnational decision makers.

Deflecting the initial charge from Paul, Philip comes back with strong jabs, touting his map's ability to directly link to risk assessment decisions. Citing its ability to be combined with information on the probability of an upcoming El Niño and La Niña, he contends that his map can identify areas likely to see an increase in damages and impacted population.

Pietro steps in before tempers flare, citing a question from a "user" in the audience: if the end goal is to influence decision making, why is there so much more time spent on developing the maps compared to interacting with the users? This is a great point that will surely be brought up in the discussion after the slam.

Conclusions and Next Steps

Bringing climate information users and developers together in a fun, energetic, yet thought-provoking forum afforded a new type of discussion on the topic. But a MapSlam alone might not have been able to accomplish the goals of the session without a rich follow-up discussion. The interactive peer learning conversation that followed the MapSlam brought the fast-paced event down to a level where slams on potentially deficient maps could be digested and scrutinized, and where a number of important points could emerge.

Floods and drought may come to mind when thinking about El Niño and La Niña, but it is important to note that increased forecasting skill could drive increased socioeconomic growth if uncertainty is properly managed. In a year without El Niño or La Niña, seasonal forecasts have less confidence to indicate where and in which months rainfall will be above or below average. But shifts in rainfall may still be substantial in these "normal" years and thus potentially important for risk managers to acknowledge. In years where El Niño or La Niña is present, the ability to predict the shifts in rainfall is typically much greater, and thus the certainty of realizing those shifts can drastically increase. With knowledge that increased rainfall is highly probable over the next three months, risk managers could take action that would lead to shifts in resources, such as allocating funds away from projects that could be less effective if implemented in a very rainy period. Resources could instead be shifted to target actions that might thrive in rainy conditions, such as particular agricultural or dam management practices.

In addition to illuminating the benefits of increased forecasting skill, the interaction between users and developers could lead to a better understanding of thresholds. Many users would like to take action based on forecast information, but action usually requires funding—and funding demands accountability and an understanding of uncertainty. In a developing country context, the opportunity cost of reallocation of funds could be high if the risk is not properly understood and accounted for. Increased dialogue between users and developers could lead to the joint development of thresholds within maps and other communication products that could directly inform users when to take action.

With forecasts increasing in skill, opportunities for interaction between the user groups are increasing and could lead to a more optimal use of the available climate information. A common space for developers using similar climate data sets would allow developers producing differentiated products to debate their methods and approaches, and would offer observers exposure to available products. With increased forecast skill, a better understanding of user perceptions, and more frequent and unique modes of interaction between users and developers, misconceptions about climate risk could be addressed and risk management improved.

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Data

In Nepal, the Safer Schools Program is working closely with the government and partners like ADB, JICA, UNICEF, and USAID to help protect the lives of students and keep educational disruptions to a minimum. Photo credit: NayanTara Gurung Kakshapati.

Global School Safety: Reaching for Scale through Innovation

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The Incomplete Bridge for Global Safety

Education is not only a basic human right, but also fundamental to development and growth. Recognizing this truth, countries around the world have been increasing investment in education. Over the last decade, governments, multilateral and bilateral development institutions, and nongovernmental agencies have been engaged in efforts to make schools resilient to natural hazards. Nevertheless, most countries continue to demonstrate limited progress. With a few exceptions, most efforts have not gone beyond the pilot stage.

If countries can make a few hundred schools safe, why are they unable to adopt a long-term approach that would make 15,000 or 150,000 schools safe?

One reason is that the data and tools required to move beyond pilot projects are often unavailable. Most ministries of education do not have the georeferenced school infrastructure inventory that is needed for analyzing the level of schools' exposure and vulnerability. Thus countries have trouble determining what their needs are, and trouble developing multiyear risk-informed school infrastructure strategies. In addition, many countries lack the tools and processes to collect vulnerability information after a disaster; the large-scale assessments of affected school infrastructure generally focus only on damage. Without this vulnerability information, the opportunity to plan and implement long-term risk-informed school infrastructure programs can be easily lost.

Making the Case to Reach Scale

Scale on global safety can be reached both for baselines and for planning:

- In countries where information is unavailable, scale can be reached for baselines by using global data to inform school infrastructure programs. Countries can also scale up from pilots to nationwide programs.
- Scale can be reached for planning by preparing the basis for long-term risk reduction programs while planning postdisaster recovery and reconstruction efforts or short-term risk reduction efforts.

Scaling up risk reduction projects requires increased access to financing as well as improvements related to planning and implementation. These improvements include use of a systematic approach to identifying and prioritizing schools for reconstruction and retrofitting, and optimization of engineering solutions.

Scaling up risk reduction projects also requires that discussion of available new holistic approaches and technologies be integrated and open to governments, the development community, academia, and the private sector.

How can innovation be used to accelerate and scale up the implementation of risk reduction programs? The case studies described below provide some answers to this question.

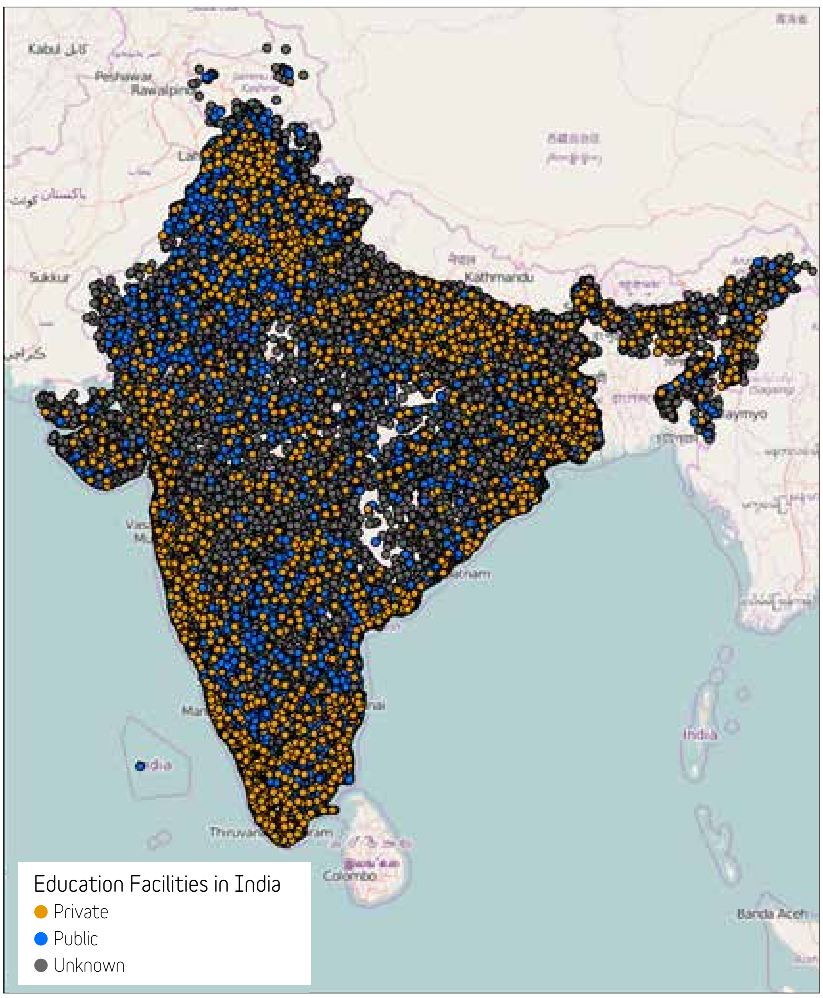
Ongoing Innovative Efforts to Reach Scale in the Education Sector: Case Studies

Using Big Data to Establish a Global Baseline for School Safety

In seeking to improve school safety, the starting point for any country is the quantification of the number of schools exposed to disasters. An enormous amount of information about school locations is scattered across platforms and social media networks, such as OpenStreetMap, Wikimapia, Foursquare, and Facebook. Analyzing this information requires revising billions of social media activities from across the world in many languages.

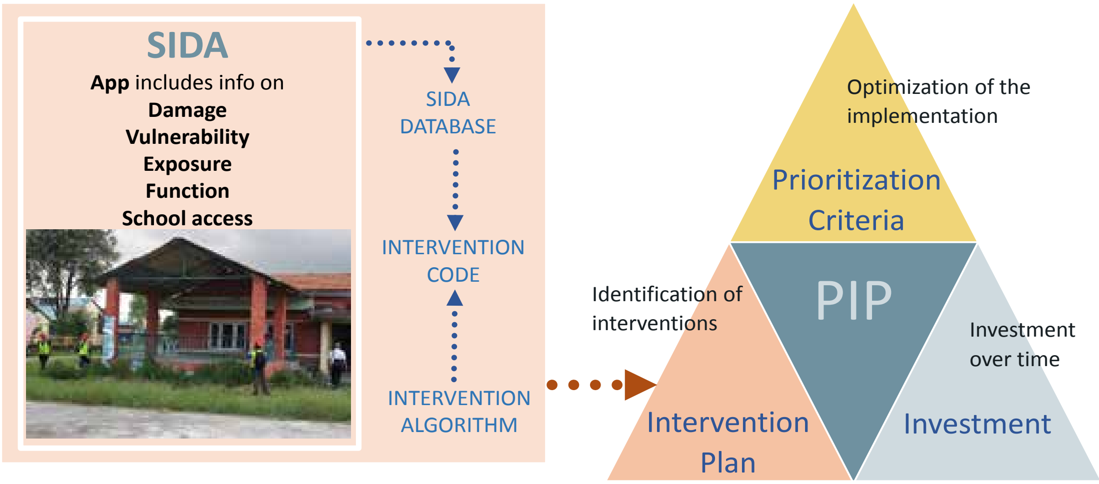
An unprecedented effort to use data mining to build a global georeferenced school database has been undertaken by Courage Services. This geospatial analytics company has used automated mining, web scraping, and automated geocoding to identify the location of about 2.5 million schools for more than 30 countries (see e.g. figure 1).

Figure 1. Schools identified in India through data mining.



Source: Courage Services, 2016.

Figure 2. Components of the prioritized investment plan (PIP): Intervention plan, which defines the interventions by automatically running an intervention algorithm against the SIDA database; investment needed to implement the intervention plan; and prioritization criteria.



Source: World Bank/GFDRR Global Program for Safer Schools.

Reaching Scale While Ensuring Quality of Postdisaster Structural Integrity and Damage Assessments: The Case of Nepal

The 7.8 Mw earthquake that struck Nepal on April 25, 2015, affected more than half of the country's 75 districts. Under the Global Program for Safer Schools, the World Bank and Global Facility for Disaster Reduction and Recovery (GFDRR) have been providing technical advice and support to the Department of Education on the planning for reconstruction and recovery of the education sector. The Safer Schools program has trained 70 Nepali engineers to conduct a detailed structural integrity and damage assessment (SIDA) of 18,000 public school buildings—an effort enabled by innovation in data collection and analysis.

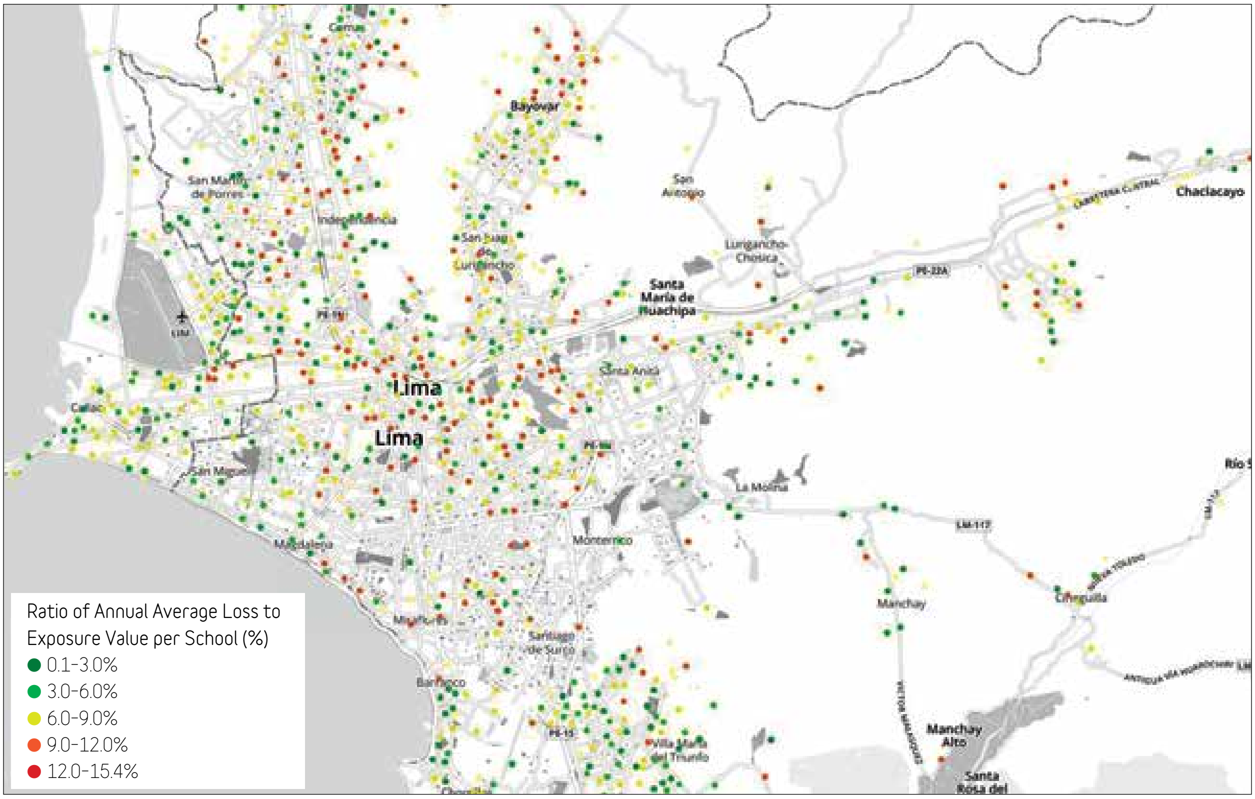
The results of the SIDA not only served as essential inputs for the Department of Education and other development partners and NGOs involved in planning the reconstruction and prioritizing the implementation; they also provided the vulnerability information needed to plan long-term risk reduction programs in the education sector. An innovative tool has been developed that automatically analyzes the SIDA results and prepares a prioritized investment plan (PIP) for use in planning the reconstruction and retrofitting of school infrastructure (figure 2). The tool makes it possible to quantify the investment needed in the short and medium terms to recover from the disaster, the investment needed in the long term to improve the resilience of school infrastructure, and the changes in the investment over time. This tool and the results of the SIDA have been integrated into a web-based platform for long-term support to risk-informed decision making in the education sector.

Thinking Differently about Prioritization of Schools at Risk to Accelerate the Pace of Retrofitting: The Case of Peru

Based on the first (2014) nationwide School Infrastructure Census conducted by Peru's Ministry of Education, there are over 40,000 public school facilities with 300,000 school buildings in Peru. The World Bank and GFDRR through the Global Program for Safer Schools supported the first probabilistic seismic risk assessment of Peru's public school infrastructure at the national level (figure 3).

This assessment, carried out by Universidad de los Andes, quantified the risk associated with all structural typologies of school infrastructure, identifying the most vulnerable cases and quantifying the benefit of risk reduction interventions over time throughout the country. These results served

Figure 3. Probabilistic risk assessment showing ratio of annual average loss to exposure value per school (percent) in Lima Metropolitan Area.



Source: World Bank/GFDRR Global Program for Safer Schools.

as a fundamental input for the planning and prioritization of national risk reduction programs in the education sector by the Ministry of Education and regional governments.

In order to enhance and accelerate the implementation of these programs, an innovative solution based on incremental retrofitting is being implemented for the first time in Peru. In line with this approach, the Safer Schools program has also convened the best universities in Peru to devise, test, and validate retrofitting solutions for one of the most common and vulnerable school typologies.

Bringing Retrofitting and Reconstruction of School Infrastructure Up to Scale: The Case of Turkey

Turkey, one of the most earthquake-prone countries in the world, has a large student community of 17.5 million and a vast stock of 85,000 schools. Over 60 percent of students attend schools located in areas with the highest hazard levels in the country. According to studies conducted by the Ministry of Education, Turkey has at least 30,000 schools built before 1998 (when advanced regulations for earthquake resistance were first enforced) and therefore likely to be highly vulnerable.

Turkey has already successfully implemented a risk reduction program for 600 schools in Istanbul; schools are being reconstructed and retrofitted at a rate of 200 per year. The Ministry of Education is now preparing a program that will scale this effort up to cover thousands of schools across the country, while also aiming to build 8,000 new safer schools in the next decade.

To scale up the reconstruction and retrofitting efforts, the Ministry of Education is using prioritization criteria—based on multiple parameters, such as hazard level, number of students, significance to emergency planning, and technical specifications of the buildings—to assess the

Table 1. Challenges and Recommendations for Reaching Scale on Global School Safety

	Challenge	Recommendation
Building evidence on global safety	• Lack of up-to-date school infrastructure inventories • Dispersed information on school infrastructure that is not fit for the purpose of risk analysis • Data gaps arising from uneven access to technology (urban vs. rural/remote areas)	• Merge big data with government data, when government data are lacking or incomplete • In postdisaster contexts, collect both the information required to plan the reconstruction and the information required to plan long-term risk reduction programs, whenever the latter is lacking or is not updated • Integrate the information in a consistent and systematic georeferenced database that can effectively support long-term risk-informed decision making in the education sector • Implement a monitoring strategy to effectively update information regularly
Using innovation for scaling up action	• Modification/adaption of established practices • Institutional and regulatory reforms • Lack of local capacity to implement innovative approaches	• Open the discussion to government, academia, development community, and private sector • Open channels for dissemination of knowledge and capacity building between academia/research institutions/private sector and Ministry of Education and other government agencies
Planning of school infrastructure programs	• Large building stock requiring intervention • Multiple implementing agents • Diverse local contexts requiring alternative approaches	• Apply an evidence-based prioritization strategy to implement school infrastructure programs over time, with clearly identified intermediate goals and quantified costs/benefits • Develop dynamic tools and methods that allow optimization of solutions and improvement of the plans over time • Open the discussion to national and local governments, development partners, and private sector

vulnerability of schools and design interventions to improve their safety. With the technical support of the World Bank, a georeferenced inventory of school infrastructure and probabilistic risk assessment are being prepared to plan a long-term investment strategy for reducing risk nationwide.

Challenges and Recommendations

Reaching scale on global school safety requires the implementation of a strategic approach that normally includes technical, institutional, financial, and/or social reforms. While innovation is a key means to foster the implementation of these reforms, innovation triggers new challenges in itself. Table 1 summarizes challenges presented by efforts to scale up global school safety as well as recommendations for meeting these challenges.

Conclusions

The synergy of technology and knowledge has spurred unprecedented levels of innovation and progress in improving the safety of schools. If this synergy is effectively harnessed to plan and implement reconstruction and risk reduction programs in the education sector—and if local implementing agents have access to the tools it has given rise to—the potential to make all school facilities safe from natural hazards in one generation is great.

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Youth from Nepal Scouts from Kaski District learn to map in OpenStreeetMap. Photo credit: Kathmandu Living Labs.

Bridging the Divide: Digital Humanitarians and the Nepal Earthquake

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Introduction

The earthquake that hit Nepal on April 25, 2015, killed over 8,000 people and injured over 20,000. This is the worst natural disaster in Nepal's history since the 1934 earthquake. With its epicenter in Gorkha District, it destroyed over half a million houses and left hundreds of thousands of people homeless. It also triggered avalanches in mountainous areas that buried hundreds of people and caused landslides in hilly areas that made already difficult-to-access rural villages even harder to reach.

The authorities planning and coordinating the postdisaster response and relief work needed a full understanding of the situation, specifically about damages, victims, and victims' needs. Because the earthquake affected over 30 of Nepal's 75 districts, collecting these data—most of them georeferenced—became one of the most challenging tasks for authorities. Compounding the difficulty was the ongoing evolution of the postdisaster situation.

The experience of the digital response in Nepal raises important questions:

- How do we collect such a massive volume of rapidly changing georeferenced data?
- Since the response and relief work need to be carried out rapidly, what are the fastest sources of information?
- How can we use data to ensure the most effective coordination and resource mobilization among response and relief agencies?

While these questions have been asked during other major disasters, the 2015 Nepal earthquake offers some insights toward their answer. Data obtained through citizen mapping, crowdsourcing, and social media were heavily used in responding to the Nepal earthquake. The discussion below describes how the formal response agencies and digital volunteer communities were brought together to make optimal use of emerging sources of data, technology, and people.

Background and the Case

In summer of 2011, a group of open source and open data enthusiasts met in Nepal to discuss how to start and advance OpenStreetMap (OSM). A series of presentations, mapping workshops, and university outreach activities followed. In late 2012, the Global Facility for Disaster Reduction and Recovery started its Open Data for Resilience Initiative (OpenDRI) in Kathmandu. OpenDRI helped to stimulate Nepal's then-nascent OSM community. It made it possible to assemble and train a few full-time mappers and a project lead who were already passionate about OSM and open data. The team mapped and collected exposure data for all schools and most health facilities in the Kathmandu Valley. The team also raised awareness among Nepal's larger youth community and mobilized youth in mapping other features such as road networks, financial institutions, and sources of food. The OpenDRI project continued for about a year, and during this period, the Kathmandu Valley was mapped quite well: dozens of mapping parties were organized, and several hundred local mappers were trained in mapping. In late 2013, when the OpenDRI project ended, the project members decided to institute Kathmandu Living Labs (KLL).

KLL has continued to expand and deepen OpenStreetMap work in Nepal. It has worked with major humanitarian organizations, including the Nepal Red Cross, National Society of Earthquake Technology, and Rotary Clubs. While KLL's wheelchair mapping was carried out in different parts of the country, its on-the-ground work focused mostly in cities in southern Nepal (e.g., Bharatpur, Biratnagar, and Rajbiraj).

Unfortunately, with the exception of the Kathmandu Valley, the districts that were hard hit by the 2015 earthquake had not been well mapped before the event. Although OSM data were missing for these districts, KLL had the staff, experience, and expertise needed to carry out the mapping. KLL understood that maps serve as vital information infrastructure in response and relief work following a major disaster. It also understood that the international mapping community was available to help. KLL therefore established communication with the Humanitarian OpenStreetMap Team (HOT)—a part of the greater OSM community—within the first 24 hours after the earthquake and partnered with the international mapping community to map the districts affected by the earthquake. For the Nepal response, over 9,000 global mappers joined the local mapping community to map or improve data in key areas as coordinated by the KLL team. HOT and KLL collaborated with business partners (including Digital Globe, Airbus, and Mapbox) to obtain and process postdisaster imagery. There were numerous mapping parties organized in cities around the world, including the one at the White House in Washington, DC. Those mapping parties were mainly organized by OSM communities, universities, and the Missing Maps community with support from the American Red Cross, British Red Cross, and Medicine Sans Frontieres.

In addition to OpenStreetMap, KLL deployed a crowdsourced reporting site—Quakemap.org—to enable people to report victims' needs as well as the fast-changing local situation. A large digital humanitarian contingent worked on all aspects of Quakemap information management, including sharing actionable social data. KLL worked to the utmost to ensure that the loops between information creation and use were closed—that is, that every report coming to Quakemap.org was looked into and acted upon,

KLL understood that maps serve as vital information infrastructure in response and relief work following a major disaster.

and that OSM data were used by response agencies.

Challenges

This effort to provide needed mapping data postdisaster entailed a number of challenges:

- *Coordination.* It was challenging to coordinate different types of groups working at different levels, such as international volunteers, local volunteers and self-organizing groups, government and other formal response agencies, and technical groups. Different time zones, diverse knowledge and processes, and different cultural backgrounds made the coordination task challenging.
- *Ensuring effective use of data.* With different groups and institutions producing data after the disaster, it was difficult for response agencies to identify good sources of data. This situation strained agencies' limited capacity and experience to process, manage, and effectively use data in their operation.
- *Data validation and curation.* Most people were more interested in creating data than carrying out the more tedious tasks of validating and curating data. HOT and other digital communities are developing trainings and processes to overcome these obstacles.
- *Updating status (especially in Quakemap).* While agencies used the Quakemap reports to design and execute their operations, they did not always update the status of the reports. This failure to provide status updates increased the chances that multiple agencies would seek to provide relief materials to the same victims.
- *Dealing with organizational and group positioning.* Some organizations and groups positioned themselves to gain visibility and access to resources. This behavior made it difficult to predict the organizations' trajectory in earthquake response space.
- *Exhaustion of the digital team.* This effort was KLL's first direct involvement in a digital response, and team members worked almost around the clock for the first several days in the midst of chaos, fear, and several other practical difficulties. Saving the team from getting burnout yet mobilizing them in effective response work was a challenge.

Recommendations

Based on the experience in Nepal, we recommend the following:

- *Invest beforehand.* Don't wait for a disaster. The major reason why KLL could effectively coordinate with formal response agencies, international volunteer technical communities, and self-organizing local groups is that it had an established network, technical experience, and credibility developed through years of work. For example, we had already worked with the Ushahidi platform to map schools; we had an existing network with local youth through mapping parties; and we had supported HOT in mapping previous disasters in other countries.
- *Identify local champions, create local institutions, and develop in-country capacity.* All these steps are crucial. Disasters are local events, and the actual first responders are the local people who observe and experience the situation, inform and report to authorities, and help victims. Local groups have the advantage of language, culture, local networks, and trust. The most valuable information comes from local people and institutions. Creating local groups and institutions and supporting their capacity building should be considered cornerstones of effective digital response.
- *Value agility.* Everything needs to be done swiftly after a disaster. Being able to provide critical information quickly not only reduces human casualties, suffering, and loss of property, it also helps to gain the trust of both the response community and victims. Coordination of digital information and data needs is an ongoing global effort. From coordinated data scrambles to online and in-person training, there are opportunities to meet some of the technical goals set out by the Sendai Framework, Sustainable Development Goals,

and various partnerships and alliances as established at the World Humanitarian Summit.

- *Minimize bureaucracy.* No single individual or institution can respond to a disaster alone, but garnering contributions from large numbers of people requires openness to new ideas. This flexibility will help in harnessing people's collective power.

Conclusions

Every disaster is different, and hence it is difficult to plan in detail ahead of time for effective response. Investment beforehand in creating and sustaining a vibrant local tech group can prove to be the most useful approach. The prior experience of such groups will enable them to quickly put together needed technology, data, and people along with their network. In the case of the 2015 Nepal earthquake response, there were at least two vital assets already in place: a vibrant civic tech team with relevant experience and expertise, and open map data for major cities hit by the earthquake. The experience in Nepal demonstrated the possibility of bringing global digital communities like HOT, teams like Humanity Road, technical companies like Mapbox, humanitarian groups like Missing Maps, and broader digital humanitarian communities together with teams like KLL on the ground. The potential of combining digital surge support globally with focused efforts by local tech groups continues to be a large opportunity for effective disaster response.

Ongoing challenges for digital disaster response include coordinating participants and organizations, differentiating between information and noise, motivating and managing the local tech teams, and ensuring that the data created through the efforts of multiple digital volunteers are actually used in operation on the ground. The Nepal earthquake has helped to advance our collective understanding for a more effective disaster response in the future.

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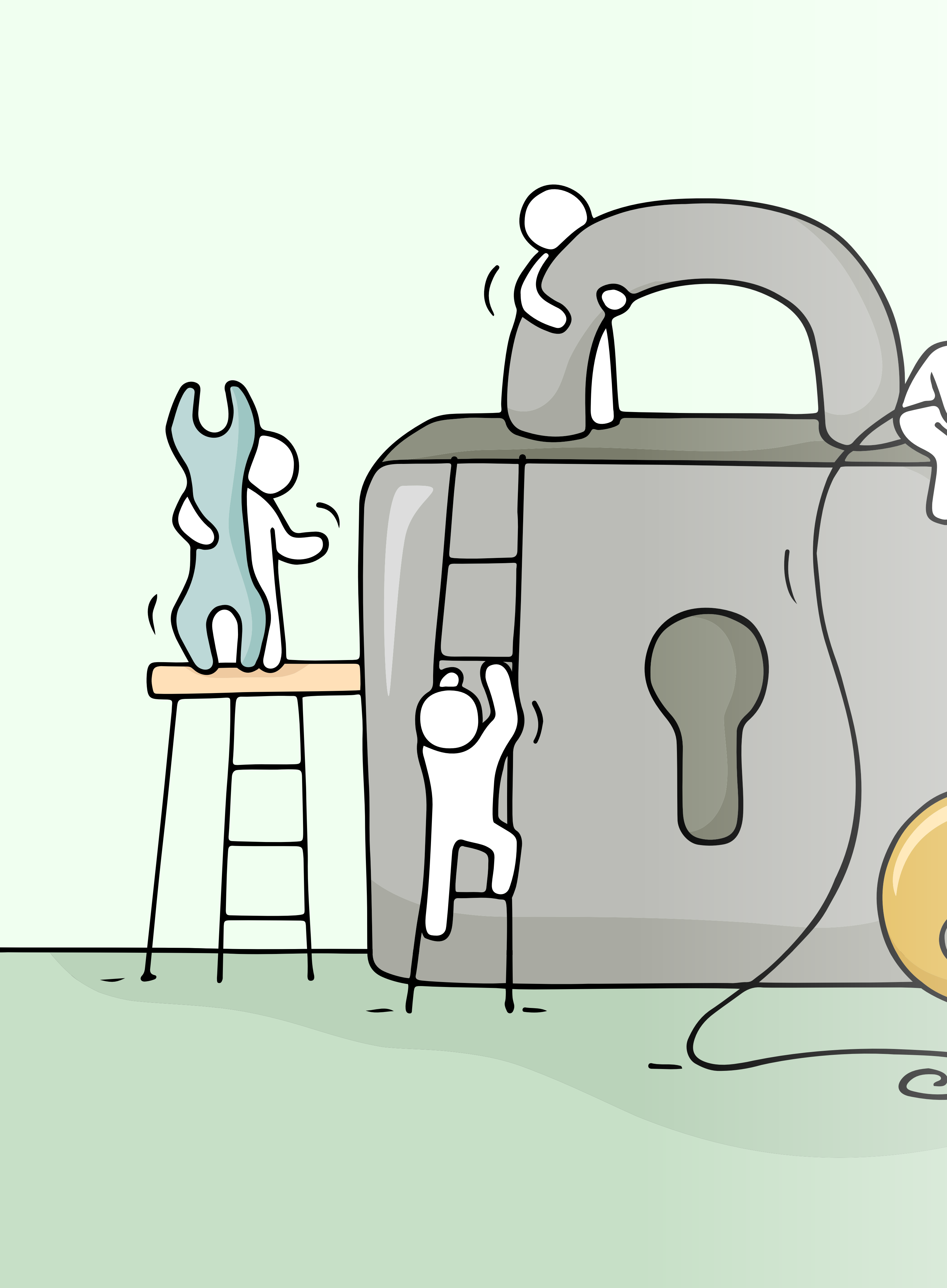
Vivien Deparday, part of GFDRR's OpenDRI team, trains UR2016 attendees on OpenStreetMap to assist in the response to the Sri Lanka floods that started on May 14. Photo credit: Emanuele Basso.

Framework | Ocean Conservancy | ODA PMU of Can Tho City | OECD | Office of Disaster Preparedness and Emergency Management, Jamaica | Office of the Prime Minister, Uganda | Ohaha Family Foundation | Onur Seemann Consulting Overseas Development Institute | OYO Corporation Palisade | PAMCZC Project Implementation Unit | Peace Development Awareness Campaign | Perastra Management Group | Perkins+Will | Philippine Disaster Resilience Foundation | Piensa Labs S.A.S | Planning from the Future Politecnico di Milano Politecnico di Torino | Potentiel 3.0 | PREDICT Services | Prime Ministry Disaster and Emergency Management Authority, Turkey | Project Coordination Unit, Ministry of Finance, Grenada | Projonma Academy | Protezione Civile, Italia | Public Health England | Punjab Emergency Service (Rescue1122) | Purdue University | Qatar Computing Research Institute | Red Cross Denmark | Red Cross Red Crescent Climate Centre | RenaissanceRe | Resurgence | Revenue (Disaster Management) Dept., Govt. of Andhra Pradesh, India | Rice University | riocom | Risk Society | RMS (Risk Management Solutions) | RMSI Private Limited Rosenbauer International AG | Rural Uplift Centre | Rwanda Youth Alliance for Climate Actions | Secretariat of the Pacific Community | Sécurité Civile | Seychelles, Division of Risk and Disaster Management | Skoll Global Threats Fund | Society For Idea In Rural & Social Development | Sriwijaya University | St Mary's College of Maryland | Stanford University | Start Network | State Ministry of Disaster Relief and Humanitarian Assistance, Afghanistan | Superintendencia de Banca, Seguros y AFP, Perú | Sustainable Futures Suza | Swayam Shikshan Prayog | Swiss Reinsurance Company Ltd. | Taha Enterprises | Techno Angle International Ltd Technology Managment Center of Yerevan City | Tekirdağ AFAD | The Geneva Association | The GovLab @New York University The Open University | The State Service for Regulation and Supervision of Financial Market under the Government, Kyrgyz Republic | Tulane University's Disaster Resilience Leadership Academy | Uganda Bureau of Statistics | Uganda Red Cross Society UK Department for International Development | UK Met Office | UK Research Councils UME School-IUSS Pavia-INGV-JRC Ispra UN Development Programme (UNDP) | UN Economic and Social Commission for West Asia | UN Environment Programme | UN Institute for Training and Research (UNITAR)-UN Operational Satellite Applications Programme (UNOSAT) | UN Major Group for Children and Youth (UN MGCY) | UN Office for Project Services (UNOPS) | UN Office for the Coordination of Humanitarian Affairs (UNOCHA) | UN World Food Programme (WFP) | UNESCO-IHE Institute for Water Education | UNICEF | Unilever Indonesia | Unite de Coordination de Projet de la Direction de la Protection Civile, Haiti | United Nations | United Nations University (UNU) | United Nations University, Institute for Environment and Human Security (UNU-EHS) | United Technique d'Execution-Ministere de l'Economie et des Finances, Haiti | Università Ca'Foscari Venezia | Università di Napoli Federico II-Centro Studi PLINIVS-LUPT Universitat Politechnica de Catalunya | Universite de Lausanne | Université Libre de Bruxelles | University College London University IUAV of Venice | University of Amsterdam | University of Annaba-Algeria University of Auckland | University of Bristol | University of Canterbury | University of Padova | University of Pavia-EUCENTRE | University of Portsmouth, UK | University of South Carolina University of Strasbourg | University of Strathclyde | University of Tokyo | University of Wisconsin-Madison | Urban Job Creation and Food Security Agency, Ethiopia | US Agency for International Development (USAID) | Ushahidi | Venice International University Vietnam, Disaster Management Center | Vizonomy | VU Amsterdam, Institute for Environmental Studies | WeFarm | Women In Slum Economic Empowerment (WISEEP-GHANA) | World Bank Group | World Meteorological Organization | World Resources Institute | World Vision | Yale University, School of Forestry and Environmental Studies | Youth Entrepreneurship for Emerging Africa | Zambia, Disaster Management and Mitigation Unit | Zurich Insurance



Breaking Barriers for the Common Good: Open Data and Shared Risk Analysis in Support of Multilateral Action

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Introduction

As advances in open data and shared risk analysis take place, it is possible to envisage a future where they underpin collaborative and coordinated action between government, the private sector, civil society, and the international community.

Background and Concepts

The quality of risk information for crisis and disaster prevention, preparedness, and response is increasing. However, it is often sector-specific and not widely available to decision makers and other stakeholders. Open data policies and practices can increase the quality and availability of information for managing crisis and disaster risk, and involve a broader section of the population in the challenge of building resilience.

To be most effective, risk information needs to be translated into shared analysis that governments and their partners can use together to manage risks. Open and shared risk analysis can help overcome institutional barriers between governments, development institutions, disaster risk reduction (DRR) practitioners, and humanitarian and other multilateral actors.

Case Studies

The following projects suggest the range of work currently being done to advance open data and shared risk analysis.

OpenDRI

The Open Data for Resilience Initiative (OpenDRI) is a project of the Global Facility for Disaster Reduction and Recovery (GFDRR). Launched in 2011, OpenDRI seeks to bring the philosophies and practices of the global open data movement to bear on the challenges of reducing vulnerability to natural hazards and the impacts of climate change. OpenDRI has been active in over 35 countries around the world in efforts to improve the sharing, collection, and communication of risk information.

OpenDRI's 2016 *Policy Note and Principles* (GFDRR 2016) describes the approach taken by the OpenDRI team to designing and implementing impactful and sustainable projects with partner organizations and communities. It lists nine principles, five on how risk information should be created, managed, and used, and four on how projects should be designed and institutional partners should interact. Examples from past OpenDRI projects and suggestions for relevant resources are also included.

PacRIS

The Secretariat of the Pacific Community (SPC) has partnered with the Open Data for Resilience Initiative since 2011 to develop and manage the Pacific Risk Information System (PacRIS). Compiled by the SPC Applied GeoScience and Technology Division (SOPAC) under the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), PacRIS is a geographic information system (GIS) platform designed to provide Pacific Island Countries, development partners, and the private sector with the data and tools needed to develop DRR applications.

SOPAC encourages member countries, partners, and the private sector to use the PacRIS platform to develop DRR solutions—including integrated financial, technical, and planning solutions—that will reduce the vulnerability of Pacific Island Countries to natural disasters and climate change. PCRAFI is supporting the first set of applications using the PacRIS platform. These include the development of a risk financing and insurance pool for the Pacific, disaster response planning applications for selected locations, and a postdisaster assessment tool.

PCRAFI is a joint initiative of SOPAC/SPC, the World Bank, and the Asian Development Bank; it receives financial support from the government of Japan and the GFDRR, and technical support from AIR Worldwide, GNS Science, Geoscience Australia, Pacific Disaster Center, OpenGeo, and GFDRR Labs.

Disaster risk data should be open by default; accessible, licensed, and documented; cocreated; locally owned; and communicated in ways that meet needs of diverse users.

MASDAP

The Malawi Spatial Data Portal (MASDAP) was established in 2012 to increase access to spatial data in Malawi and to improve collaborative use of the data by the government of Malawi, the public, and other key stakeholders. In order to set up, manage, and maintain the technical platform and its data, a MASDAP working group was created comprising the key stakeholders involved in producing or using risk information. Originally, the working group was created around the technical team and implementation agencies involved in the Shire River Basin Management Program, the project MASDAP originally supported. Over time, as the working group has undertaken more general management of the platform at the national level, it has expanded to include institutions such as the National Statistics Office, Surveys Department, Department of Climate Change and Meteorological Services, Agricultural Development Division, Department of Disaster Management, Water Resources, and Malawi's Polytechnic College and Chancellor College.

Examples of activities undertaken by the working group include (1) holding regular meetings and sharing communications; (2) holding awareness campaigns for different stakeholders;

(3) conducting trainings and building capacity on the use of the MASDAP platform and other related tools; (4) providing feedback to improve the functionality of the MASDAP platform; (5) developing a policy framework for sharing geospatial and other required data among stakeholders, and defining minimum metadata and data quality requirements; (6) ensuring that baseline data required for postdisaster assessments are collated and are available in ready-to-use open format; and (7) coordinating and developing the strategy for the collection and use of the data gathered using community mapping techniques. In the southern region of Malawi, a subgroup of the national forum has been created to focus specifically on issues of data access and availability in this area.

Start Network Projects

Start Network is undertaking several projects demonstrating collaborative analysis, with a focus on preparedness and early warning:

- *Start Fund's experiment with applying blockchain technology.* This project aims at enabling radical transparency of decision making and funding flows.
- *The Forecast-based Warning Analysis and Response Network,* or FOREWARN. This is the Start Network's interagency risk analysis group, which fulfills a technical advisory role to the Start Fund Crisis Anticipation Window.
- *Start Network's partnership with a forecasting group to adapt research on prediction techniques to humanitarian action.* The FOREWARN group will be trained in forecasting techniques and will take part in a forecasting tournament aimed at shedding light on how humanitarian agencies can forecast more effectively and thus improve risk management and early response.

INFORM

INFORM is a global, open source index that assesses countries' risk of humanitarian crises and disasters. It provides a common evidence base to enable governments and organizations to work together to reduce countries' risk, build resilience, and prepare for crises. Resource allocation for preparedness, resilience, and risk reduction is not currently aligned with actual crisis risk. INFORM can provide actors with risk information and analysis that will allow them to better prioritize their interventions.

INFORM can be used for several purposes:

- *Prioritization.* The results of INFORM can be used to rank countries by risk, or by any dimension or component of risk. This information can support decisions on resource allocation.
- *Risk profiling.* The results of INFORM for a single country are a risk profile that shows the level of individual components of risk. This information can support decisions about where to focus programs designed to reduce risk.
- *Trend analysis.* The results of INFORM are available for at least five years. This allows trend analysis on the level of risk and its components.

The INFORM risk assessment methodology and development process can also be used to produce regional or national risk models. These have the same features and benefits as the global model, but are subnational (at the level of the province, municipality, or village) in resolution. Developing an INFORM subnational model is a locally owned and managed process that is supported by the global INFORM initiative. This approach ensures that each model has local buy-in, is used in local analysis and decision-making processes, and is adapted according to local risks; but also ensures that it can draw on global resources and expertise and is validated according to global standards and best practice.

Conclusions and Recommendations

- Open data can increase the availability of risk information. Government open data initiatives and other data-sharing platforms are fundamental in providing access to this information.
- Disaster risk data should be open by default; accessible, licensed, and documented; cocreated; locally owned; and

communicated in ways that meet needs of diverse users.

- Open data projects in the disaster risk space should be designed to engage user communities, develop strong institutional partnerships, prioritize open source approaches, and set clear, long-term goals.
- Resource allocation for preparedness, resilience, and risk reduction is not currently aligned with crisis risk. All actors should increase the use of risk information and analysis for prioritizing their interventions.
- Risk analysis is most useful when it is developed jointly by the relevant actors. Shared analysis is critical for ensuring that the priorities, objectives, and strategies of the different actors are complementary. Different actors have different expertise and focus, but a shared risk analysis helps them work better together.
- An open and transparent methodology and use of publicly available data make risk analysis more credible. When organizations and governments can see what data risk analysis is based on and how it is produced, they are more likely to use the data and adapt them for their own purposes.
- Risk analysis needs to be accessible to strategic decision makers. Although organizations may need to carry out their own more detailed and technical risk analysis to support programming, a simple and shared analysis can support coordination and strategic decision making and policy making—and need not be expensive.

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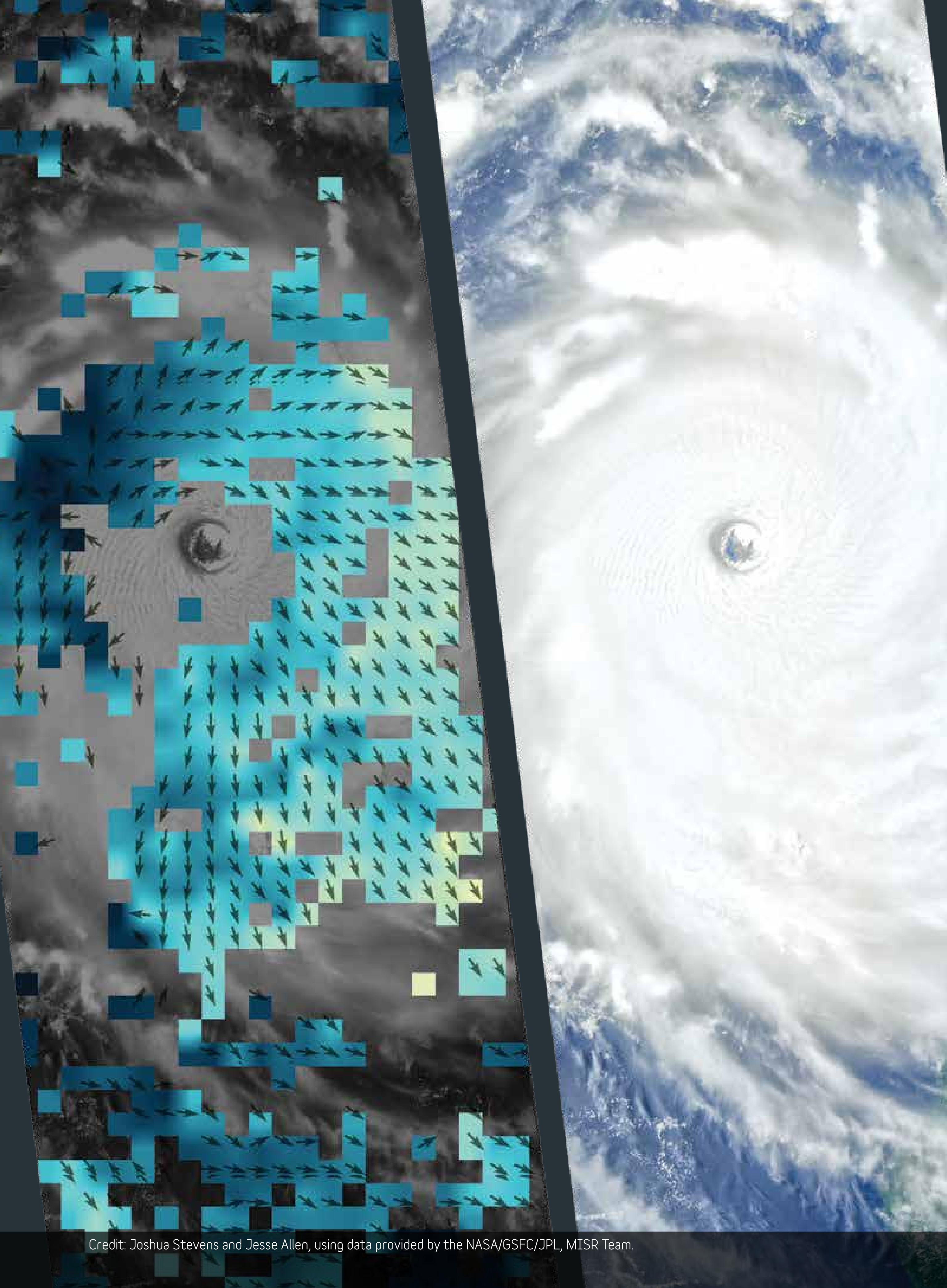
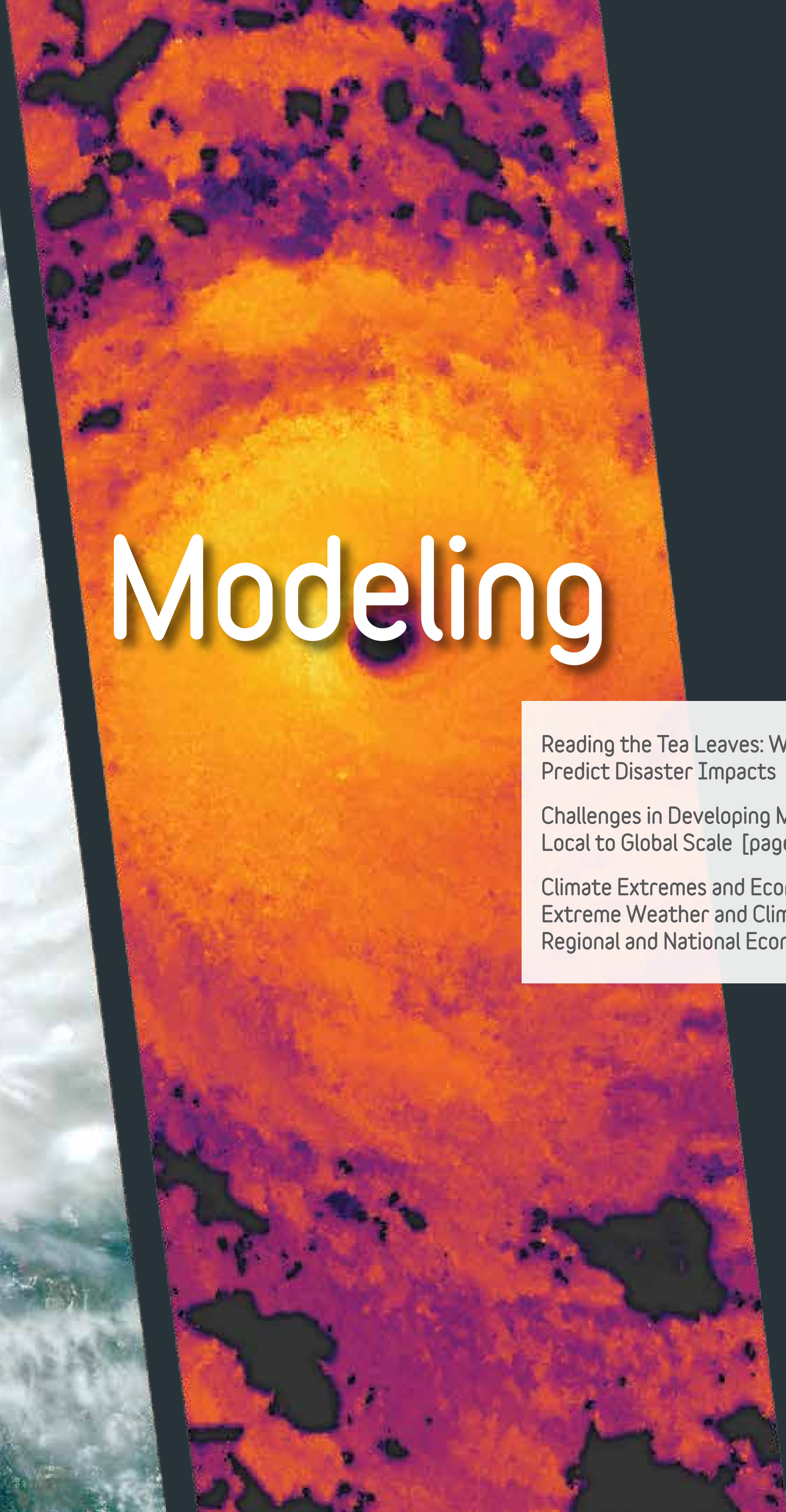
Attendees explore what is on offer at the UR2016 Expo. Photo credit: Federica Zambon.

Resource allocation for preparedness, resilience, and risk reduction is not currently aligned with crisis risk. All actors should increase the use of risk information and analysis for prioritizing their interventions.



Credit: Joshua Stevens and Jesse Allen, using data provided by the NASA/GSFC/JPL, MISR Team.



Modeling

Reading the Tea Leaves: When Risk Models Fail to Predict Disaster Impacts

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Risk models are built on the best available data—but the best data are often less than ideal. It is only when a disaster occurs that we can retrospectively assess how accurately a risk model predicted the extent and magnitude of disaster impacts. Models sometimes surprise us with their accuracy, but more often, they over- or underestimate the scale of the disaster. Postdisaster forensics offers an opportunity for determining why a risk model has failed, but in our experience this information is not being effectively utilized to improve risk models.

The effort to understand model efficacy raises several key issues.

First, model results are often not well understood by decision makers. The failure of a perfect prediction of loss is often viewed as a failure of the whole model. Once a disaster has occurred, it is too late to highlight the aphorism that "all models are wrong but some are useful."[1] If decision makers are not well versed in the purpose and scope of model results, they will not be able to use them to prioritize critical response activities or to guide longer-term recovery operations such as "building back better." Thus, the effective communication of loss modeling results is paramount to practical implementation.

Second, the dimensions of catastrophe loss modeling have evolved considerably since modeling was introduced in the early 1980s (Steinbrugge 1982). Where early estimates of loss were essentially limited to reports of building damage caused by a single peril, assessments now consider an array of secondary and higher-order effects that often require more sophisticated modeling—and that when not considered will underestimate the true impact of a disaster.

Third, technological advances such as remote sensing and emerging approaches such as crowdsourcing have not had the expected transformative impact on modeling. This is in large part due to lack of experience and validation. Remote sensing has the potential to improve loss modeling through developing exposure data—i.e., generating inventory models of buildings and critical infrastructure using moderate- and high-resolution imagery. But advances in this area will depend on robust sensor deployments and detailed validation studies using imagery at all spatial resolutions and inventory data sets collected from field surveys.

Fourth, the technological advances that have accelerated

1 This saying is commonly credited to George Box. See for example Box and Draper (1987, 424).

improvement in many areas of loss estimation modeling have not been equal across all constitutive models. To ensure the most robust estimates of risk and loss, a balanced investment in the development of the constitutive hazard, vulnerability, and exposure models is needed. That is, the reliability of an overall loss estimate is often modulated by the reliability of the least understood component of the model. With unlimited resources, exposure and vulnerability could be accurately quantified, but substantial fundamental research is still required to better constrain the physics of perils such as earthquakes, volcanic eruptions, storm surge, etc. This is especially true in developing countries, where long-term investment in fundamental science and research is particularly limited.

Finally, loss modeling has been dominated by proprietary models often used for quantifying insured losses after major disasters. That situation seems to be changing, however, and efforts are under way to develop open source models that provide transparent access to hazard, vulnerability, and exposure data for many developing regions that go beyond insured losses to include social and full economic impact. Developing these newer models entails some expense because the framework for accepting, sharing, updating, and disseminating information must be developed and must be robust enough to work with constitutive models that may be disparate in resolution and data formats (a problem that is also critical in proprietary models).

The discussion below examines each of these issues and suggests specific steps for improving our ability to accurately estimate the impacts of future disasters.

Effectively Communicating the Results of Loss Modeling

Although loss modeling for natural disasters has been around for decades, its application during the actual response to an event is fairly new and poses a particular challenge for communication of model results. With the rapid development of loss modeling and the emergence of large-scale sensor networks, including ubiquitous monitoring (satellites), researchers have pushed the notion of near real-time loss estimation as a key tool in the disaster responder's toolbox (Eguchi et al. 1997). Loss estimates for recent disasters, including earthquakes in Haiti (2010), Tohoku, Japan (2011), and Nepal (2015), have demonstrated that this type of information can aid in the physical planning for the recovery process. For decision makers to use the outputs appropriately, however, they need to better understand the development and reliability of this information; in addition, they need to adapt response protocols so that this information becomes an integral part of the postevent workflow process.

The experience of the 2010 Haiti earthquake is instructive. Decision makers reported feeling that the data (loss results) were just "parachuted in" and that they had no time to change existing protocols to effectively include them (World Bank, GFDRR, and ImageCat 2013). Appropriate and effective use of the data would require (1) creating an umbrella framework to unite multilateral agencies in a crisis and to allow materials to be combined and collectively used by all; (2) establishing response protocols that specifically include satellite-derived loss estimates; and (3) training first responders to use the loss estimate data sets. A disaster or crisis is the worst time to introduce new analytics and tools, as people will inevitably rely on the tested and trusted approaches of their standard operating procedures. To ensure that decision makers use information from risk models and real-time analysis during a crisis, we need to build capacity and trust in this information long before a disaster strikes.

Modeling Secondary Effects

Differences in modeled versus actual damage are in some cases due to limitations and uncertainties in the data. In other cases, however, they are due to more fundamental issues, such as the failure to model secondary effects. Experience from the 2010–2011 Canterbury earthquake sequence and the 2011 Tohoku earthquake indicates that loss models underestimated damage and economic losses principally because secondary perils and consequential effects were not modeled. In Canterbury, damage associated with liquefaction and rockfall was not included in loss models; and the loss models associated with subduction earthquakes in Tohoku omitted a larger-than-expected tsunami and the consequential nuclear accident at Fukushima. This same discrepancy exists for major flood or cyclone events, where models capture the impact from fluvial events relatively well, but fail to include the pluvial events (e.g., landslides or flash floods).

To ensure that decision makers use information from risk models and real-time analysis during a crisis, we need to build capacity and trust in this information long before a disaster strikes.

Enabling Disaster Response through Technology

There is no question that technology can help provide situational awareness during the response to a disaster, and decision makers often indicate that any information is better than no information at all. But there is also no question that uncoordinated, repetitive, and nonvalidated information is confusing; it cannot be helpful, for example, to receive 400 maps per day at the height of a crisis. Adoption and use of information technologies in disaster response requires a thorough postdisaster review of the success and failure of these technologies, including extraction of key lessons and actionable recommendations.

During the earthquake response in both Haiti and Christchurch, a large international community of engineers and scientists was mobilized to perform near real-time damage assessments through crowdsourcing. This approach gave hundreds of individuals access to thousands of satellite and aerial images so they could identify collapsed or damaged structures. These experiences taught two important lessons: given the many volunteers who want to help in the response to a large disaster, damage assessment protocols must be simple, clear, and easily implemented; and those using crowdsourced results to make critical response decisions must fully understand their limitations. Two other lessons emerged through postevent analysis:[2] (1) the assignment of damage grades of 4 or 5 (EMS-98 damage scale) has high reliability (greater than 70 percent), but "false negatives" are relatively common; and (2) to extrapolate the results of crowdsourced damage assessments to lower damage grades, extensive field calibration is necessary using the same damage states and descriptions. These lessons point to the importance of using postevent forensics that helps to validate and calibrate the models and procedures used to estimate disaster losses.

[2] See Booth et al. (2011); Ghosh et al. (2011); and Foulser-Piggott et al. (2016).

Balancing Model Accuracies in Overall Loss Estimates

Currently, there is little guidance for determining the right level of detail or accuracy for the three constitutive models in the loss estimation process—that is, the hazard model, which defines the severity and frequency of the hazard (e.g., flood heights and frequencies); the exposure model, which quantifies the number or value of assets exposed to the hazard (e.g., number of residential buildings); and the vulnerability model, which relates the exposed assets' susceptibility to damage or loss to specific hazard intensities. In practice, these constitutive models are convolved to estimate loss parameters (such as average annual loss or maximum probable loss) or scenario-based losses. In most cases, data sets reflecting mean values or algorithms that assume average trends are used to calculate resulting losses. However, the level of uncertainty in each model can vary widely; and these uncertainties can greatly affect the reliability or "believability" of the final results. Thus loss estimates with large bands of uncertainty, where the drivers of those uncertainties are largely unknown, are common.

Recently, there has been an attempt to quantitatively estimate the contribution that constitutive model uncertainties have on an overall loss estimate (Taylor 2015). "Robust simulation" allows analysts to use simulation methods to (1) quantitatively account for model uncertainties in complex convolutions of loss, (2) identify where individual model uncertainties drive the reliability of the overall results, and most importantly, (3) determine where model improvements can help drive down the overall uncertainty of a loss result. This type of approach can facilitate a more balanced investment in model development and enhancement.

Ensuring Effective Open Source Solutions

In the last several years, practitioners have promoted open source solutions in response to the limited access offered by proprietary and expensive loss models. Most existing models are embedded in proprietary platforms designed to address (re)insurance applications. Typical issues that arise in this environment are "black box" modeling (i.e., lack of transparency), proprietary data formats, inability to mix and match the best models, difficulty in comparing model outputs from different modeling vendors, and inability to apply these models to noninsurance situations.

Several international initiatives have been established that seek to make risk data and assessment tools openly available,[3] although they still face many technical challenges. For example, while access to individual models may be straightforward, ensuring that models are compatible is more difficult. Constitutive models are built on different data sets—some for different regions of the world, and some from different time periods—so integrating these models means checking model input-output requirements and in some cases developing translational interfaces. Once these obstacles are overcome—likely in the next several years—we will be able to evaluate firsthand the benefits, costs, and efficacies of open source modeling approaches.

Summary

Although risk or loss models sometimes fail to predict the impacts of large disasters, the progress made after each event has been noteworthy. In many cases, new and innovative technologies did indeed contribute to better response and recovery results. The next decade will see further advances in model development and data collection. With a prudent program of data archiving and a meaningful commitment to model enhancement, our ability to accurately predict the effects of disasters should rise exponentially.

[3] Examples include the Global Earthquake Model (GEM) Foundation (https://www.globalquakemodel.org/) and the Oasis Loss Modeling Platform (http://www.oasislmf.org/).

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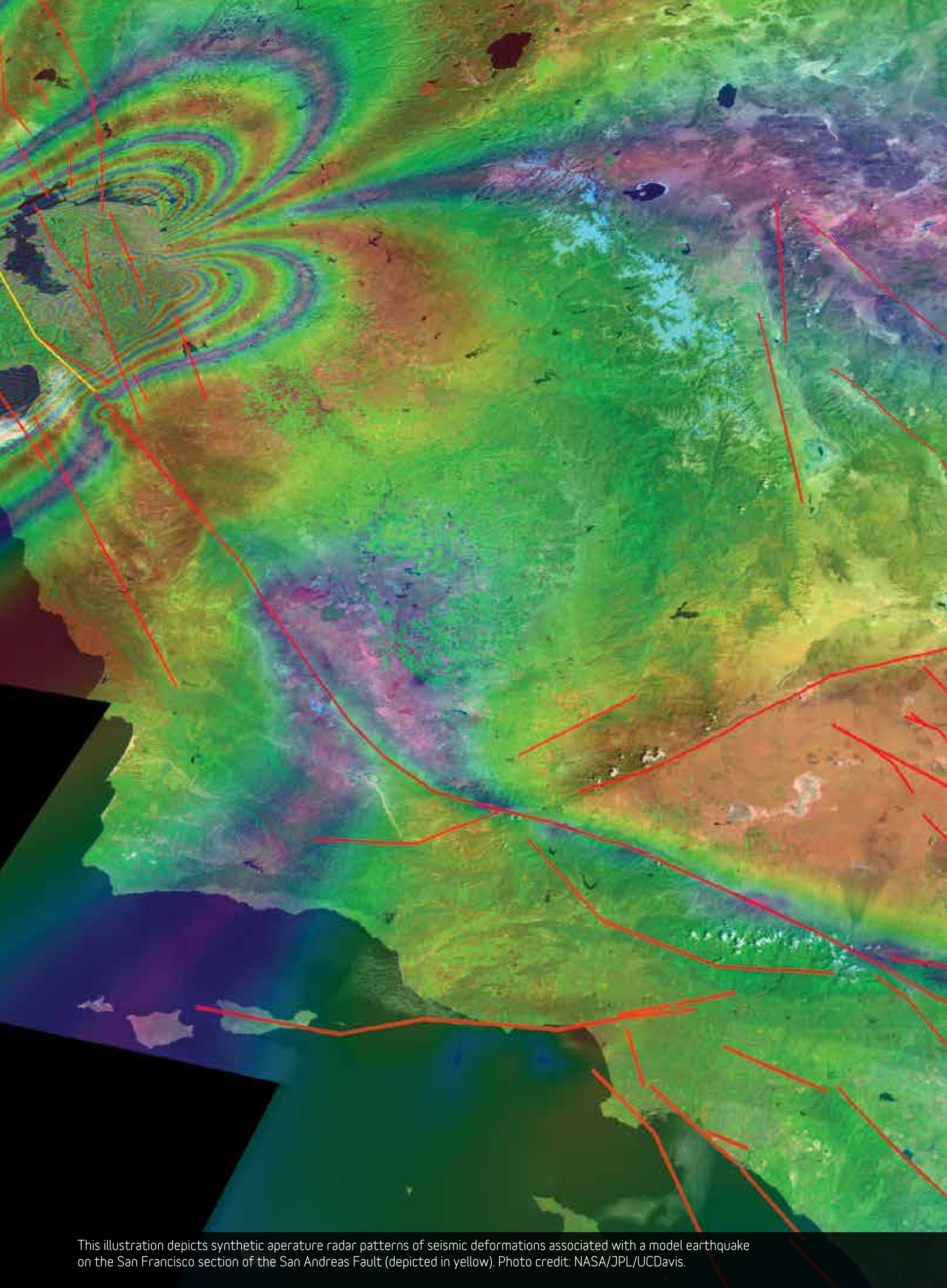

This illustration depicts synthetic aperature radar patterns of seismic deformations associated with a model earthquake on the San Francisco section of the San Andreas Fault (depicted in yellow). Photo credit: NASA/JPL/UCDavis.

Challenges in Developing Multihazard Risk Models from Local to Global Scale

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Introduction

The Sendai Framework for Disaster Risk Reduction 2015–2030 (UNISDR 2015b) calls for the development of risk information to support risk monitoring and disaster risk reduction at global, regional, national, and local levels. One particular need is for open, transparent, and credible multihazard risk assessment methods, models, and tools. But developing tools and making them available to those who need them is challenging; difficulties include limited availability of and access to data, insufficient capacity, and problems communicating risk information to decision makers (OECD Global Science Forum 2012).

Several global initiatives for different hazards have begun to address these issues by building global networks of collaborators and by sharing information, tools, and methodologies to promote the development of standards and improved capacity at national to local level. Thus far, however, the availability of comprehensive risk information needed to inform disaster risk reduction is limited, and the level of interaction across global initiatives is not very well developed.

All of the challenges in modeling single hazards are compounded for multihazard risk analysis. For instance, risk assessment methodologies for different hazards often produce risk metrics that are not comparable. In addition, hazard interactions (e.g., simultaneous occurrence of a flood and landslide) are generally neglected, resulting in strongly underestimated risk in the most exposed areas.

The discussion below looks at some of the demands for understanding multihazard risk within the civil protection community and at how several global natural hazard/risk initiatives are helping to meet this demand. It also identifies key actions required to develop a comprehensive global risk modeling capability to meet risk information needs at various scales.

A Stakeholder Perspective

Civil protection decision makers intuitively adopt a multihazard approach in everyday practice and at all scales. In Italy in particular, the civil protection system works side by side with scientists and other stakeholders toward achieving a quantitative and probabilistic multihazard risk analysis capability.

At its simplest, a multiple-risk scenario includes two (or more) uncorrelated events occurring, simply by chance, at the same place, at the same time, or separated by a lapse of time limited enough to observe an overlap of the effects. More complex scenarios must consider cases linked by a cause-effect relationship; examples like cascading effects and natural hazards triggering technological disasters show how complex and challenging implementing a fully multirisk model can be. But as modern society grows more complex, analysis of such cases is needed for the design of prevention strategies and contingency planning.

Global Modeling Initiatives

The global initiatives described below seek to meet stakeholders' need for data, models, and tools for risk assessment, though primarily within the context of single hazards. As multihazard risk modeling develops, it will draw on the tools, methodologies, and networks of these initiatives and encourage greater collaboration between them.

The Global Earthquake Model

The GEM (Global Earthquake Model) Foundation is a public-private partnership that seeks to improve understanding of earthquake risk globally.[1] It includes about 40 partner organizations as sponsors, project partners, or advisors.

GEM's OpenQuake computational modeling platform, officially launched in January 2015, freely provides access to a dozen global data sets and a variety of hazard/risk models at local to regional scales. It also provides tools for building a risk model, analyzing the risk, and interpreting and understanding the risk analysis results. The OpenQuake tools and methodologies have been utilized worldwide by over 1,000 users from more than 100 countries to prepare a range of earthquake hazard and risk models at various scales. GEM engages in capacity-building projects in developing countries and is now developing a global earthquake risk model.

The Global Flood Partnership

The Global Flood Partnership (GFP) has brought together the scientific community (De Groeve et al., 2015), service providers (satellite, weather, and hydrology), national flood and emergency management authorities, humanitarian organizations, development agencies, and donors in a partnership to better predict and manage flood disaster impacts and flood risk.[2] The GFP provides operational, globally applicable flood risk management tools and services as a complement to national capabilities. Furthermore, the partnership promotes sharing of relevant data and information, fosters in-country capacity building, and seeks to improve flood risk management models and products across different authorities and decision pathways in order to strengthen preparedness and response and reduce disaster losses.

The GFP has increased situational awareness for partners (through sharing of information and analysis) and has exploited innovation and scientific advances, but its latest challenge is to develop multi-hazard early warning systems and risk information.

The Global Volcano Model

The Global Volcano Model (GVM) is a growing international network of 50 (public and private) institutions and organizations that collectively aim to identify and reduce volcanic risks.[3] GVM includes the World Organization of Volcano Observatories, in recognition of the key role played by volcano observatories at various scales. Many volcano observatories deal with multiple natural hazards (earthquakes, landslides, tsunamis, etc.), because volcanoes, and frequently their environments, are multihazardous.

Embracing collaboration, scientific excellence, open access approaches, and public good, GVM produced a substantial collective contribution to the 2015 Global

As multihazard risk modeling develops, it will draw on the tools, methodologies, and networks of these initiatives and encourage greater collaboration between them.

1 For more information see the GEM website at https://www.globalquakemodel.org/; see also Keller and Schneider 2015.

2 For more information see the GFP website at http://gfp.jrc.ec.europa.eu/; see also De Groeve et al. 2015.

3 For more information see the GVM website at at http://globalvolcanomodel.org/.

Assessment Report (UNISDR 2015a), which includes a global comparison of volcanic threats. It also conducted the first global assessment of ash fall hazard, and is developing a series of relational databases with consideration of ontologies, standards, access, and management. Nonetheless, the understanding of volcanic risks is still limited, and volcanic risk assessments are in their infancy, owing to challenges related to the multitude of hazards, data availability, model representation, and resources.

The Global Tsunami Model

A new understanding of the threat posed by tsunamis, developed since the devastating 2004 Indian Ocean and 2011 Tohoku events, has shown the need for revised procedures to assess tsunami hazard and risk. During the last 10 years or so, probabilistic methods have been developed to assess tsunami hazard and risk, and this continues to be a rapidly developing branch of tsunami science.

The origins of the Global Tsunami Model (GTM) are in the multi-institutional work leading to a global tsunami risk analysis for the 2015 Global Assessment Report (UNISDR 2015a).[4] As a result of this successful collaboration, a global group of institutions is now creating a formal network that will have the most up-to-date tsunami science; that will define, test, and apply standards, good practices, and transparent analysis processes; and that will develop tsunami hazard and risk assessment products, tools, and approaches for use at various scales.

The International Consortium on Landslides

The International Consortium on Landslides (ICL) is an international nonprofit organization that promotes landslide research and capacity building, particularly in developing countries, and coordinates international expertise in landslide risk assessment and mitigation.[5] The network has about 70 members worldwide, mainly in Asia and Europe.

The ICL has focused considerable attention on landslide monitoring and disaster response, including organizing about 30 international missions to postdisaster locations worldwide. As part of this effort, the landslide community has carried out short-term forecasting that relies on both satellite- and land-based technologies. By contrast, probabilistic modeling for long-term landslide risk is not well-developed, perhaps because landslides are most often triggered by other hazards, especially severe rainfall/floods and earthquakes. Thus advances in probabilistic modeling and long-term forecasting depend heavily on the inclusion of landslide within a multihazard modeling framework.

Challenges

Despite the growing demand for multihazard risk assessment capabilities worldwide, and the many global initiatives and networks that develop and deliver natural hazard and risk information, the global initiatives have to date focused mainly on hazards and individual hazard domains. Moreover, while existing global initiatives recognize the importance of partnerships with local experts, connecting hazard and risk information from local to global scales remains a major challenge.

In order to move to a multihazard approach for comprehensive risk assessment, the natural hazard communities need to address a few key priorities:

- *Common principles and collective action.* Collaboration by different networks and initiatives should be founded on openness, public good, and credibility. Collective action is required across hazard and risk communities, across public and private interests, and from local to global scales. Multihazard risk assessments require both interdisciplinary perspectives and discipline-specific expertise. Networks need to be able to bridge public and private interests and to balance differing needs (for levels of detail, scale, and complexity and for the types of applications and decisions to be made). Flexibility and compromise are required to achieve consensus and to move

4 For more information see the GTM website at http://globaltsunamimodel.github.io/2015_06_IUGG/GAR_GTM_IUGG_presentation_updated_distr.pdf.

5 For more information see the ICL website at http://icl.iplhq.org/category/home-icl/.

forward in a mutually beneficial manner.

- *Understanding and accounting for hazard interactions.* A consistent multihazard approach should address both independent and concurrent hazard events, as well as dependent (or triggered) events that produce collateral damage. For example, interactions between storm surges and river flooding, which are common in river deltas, are neither well known nor well studied.
- *Harmonization of data and development of standards.* To meet the demand for high-quality data and models that are openly available, emphasis at the global level should be on developing standards, such as for common input and output formats, for sharing of data and results, and ultimately for quality assurance and credibility. Ensuring that databases are accessible and meet certain standards, for instance, will allow a variety of users to directly access information.
- *Harmonization of risk metrics and computational approaches.* There is much common ground in the numerical algorithms for scenario and probabilistic hazard and risk analysis, which are largely transferrable across hazard domains (although methodologies for treating and considering uncertainties remain a challenge). Moreover, the fundamental elements of exposure and vulnerability that form the basis for risk analysis are common to all natural hazard models. In terms of vulnerability, calculation of damage costs, injury and mortality, and social vulnerability and resilience can all be integrated into a multihazard expression of risk.
- *Making information useful at all scales and for all stakeholders.* To avoid any disconnect between decision makers and risk modeling and assessment experts, the scale and breadth of multirisk assessments needs to be identified and defined jointly. It is important to be able to offer data sets, models, and tools for developing hazard and risk models, analyzing the risk, and interpreting and understanding the analysis results.

While existing global initiatives recognize the importance of partnerships with local experts, connecting hazard and risk information from local to global scales remains a major challenge.

Conclusions

The demand for complex multihazard risk assessment capabilities that can address the needs of diverse stakeholders is increasing. At the same time, multiple global hazard/risk modeling initiatives have advanced to a point where it is now possible to develop a consistent, global, multihazard modeling capability that does the following:

- Addresses the likelihood and consequences of independent, concurrent, and triggered events
- Takes a holistic and comprehensive approach to assessing hazards and risks
- Incorporates tools and methodologies that are scalable from global to regional, national, and local levels
- Provides the opportunity to involve developers, practitioners, and stakeholders in a common framework for assessing, communicating, and reducing risk to communities worldwide

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UR2016 attendees register at the start of the main conference on May 18. Photo credit: Miki Fernández.

Climate Extremes and Economic Derail: Impacts of Extreme Weather and Climate-Related Events on Regional and National Economies

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Accounting for and Predicting the Economic Impacts of Natural Hazards

Natural hazard risks, including weather- and climate-related extreme events, are able to undo sizable development and poverty reduction efforts, upset financial and economic stability and growth, and devastate communities and individual lives. The 2015 Global Assessment Report (UNISDR 2015a) valued the global annual average losses from natural hazards as topping $300 billion, more than any previous estimate. But even this value does not account for the whole magnitude of tangible and intangible damage and losses.

The Sendai Framework for Disaster Risk Reduction (UNISDR 2015b) has made substantial reduction of disaster losses a top priority of international efforts. To assess the progress toward this end, the global disaster risk reduction (DRR) community will have to fill the gaps in the loss data records and substantially improve the practice of damage and loss assessment. Moreover, the DRR community will need to link up with the climate change community in order to value the economic impacts of climate change and the costs of extreme weather and climate events. There is ample scope for the two groups to learn from one another—and to advance knowledge beneficial to both.

The Sendai Framework represents a commitment to a transformative change in how natural and human-made risks are dealt with (van der Vegt et al. 2015; Wahlström 2015). Because disaster accountancy was largely neglected in the past, it is not an easy task, or sometimes even possible, to portray the spatial and temporal patterns of disaster damage and losses with reasonable precision. For years, the United Nations Office for Disaster Risk Reduction and the international community have worked to fill in the knowledge gaps and to promote a culture of evidence-and knowledge-based DRR. But as we try to compensate for past negligence, we should not waste the opportunity to collect information and knowledge on the full economic costs of disasters, including their ripple and spillover effects on the increasingly interconnected economies.

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Understanding the Potential Impacts of Natural Hazards

There are multiple approaches to estimating the distributions of natural hazard economic risks. Statistical approaches look at the past records of loss data, and estimate risk from historical loss data using extreme value theory. A fundamental challenge is how to model the rare phenomena that lie outside the range of any available observation, and cannot be accounted for in extreme value theory methods.

Catastrophe models—computer-based representations that estimate the potential damage of disasters (Grossi and Kunreuther 2005)—are able to perform extreme value analysis. This is usually done by overlaying the properties or assets at risk (the exposure module, such as classification based on a land cover data set) on the potential sources of natural hazards (hazard module) in a specific geographical area. A vulnerability module estimates the damage (e.g., of a hurricane) that occurs based on a function of the hazard intensity (e.g., wind speed), the environmental conditions (e.g., the region's terrain), and the exposed value characteristics (e.g., the structural types).

Because of their outputs—the potential damage to the stock of assets—catastrophe models are mainly used in the insurance industry. Over the last three decades (since the late 1980s), catastrophe models have been quite effective in contributing to the shift from reactive catastrophe reinsurance pricing to technically informed pricing. This shift has led to a more resilient catastrophe reinsurance industry: one based in scientific and technical knowledge, and more affordable to buyers. In turn, this change has allowed the development of new financial instruments for disaster risk management and climate change adaptation, including capital market products and international risk pooling. Although in the past catastrophe models have focused on a limited set of perils, such as hurricanes, earthquakes, and extreme precipitation, more and more applications are being developed for other perils, such as drought, terrorism, and pandemics, and for areas of the world that have been neglected in the past.

Assessing Wider Economic Impacts

On the other hand, the estimation of wider economic impacts of extreme weather and climate events has been less exploited by disaster risk management practitioners than damage estimates. Typically, models such as input-output (IO), computable general equilibrium (CGE), social accounting matrix (SAM), and econometric models are able to provide the impacts of extreme weather and climate events on the economic flows—for example on the production of economic sectors and the regional or national gross domestic product (GDP). Although these models have advanced over time, their effective applicability to real-world cases has been constrained by a number of factors, including their intrinsic level of uncertainty (arising from the number of assumptions) and the difficulty in modeling the complex dynamics of a system in the aftermath of a disaster.

Standard IO models are relatively simple, static, and linear models imitating the interrelationships between economic branches within a national or regional accounting system. CGE models are nonlinear models of circular flows of goods and services between agents, where representative households and firms choose their demand and supply following constrained optimization problems, taking prices as given. Prices are determined by market equilibrium conditions, allowing substitution effects and more realistic behavioral content and working of both factor and product markets compared to IO models (Rose 2004). Econometric models, based on time-series data, have the advantages of being statistically rigorous and possessing forecasting capabilities, but they can provide only estimates of the total impacts. Thus they are often unsuitable for a detailed analysis of the specific losses of a disaster.

Models of this type may also be used to inform policy making in some areas of disaster risk management, such as flood risk management (Koks and Thissen 2014) and water resources management under scarcity conditions (Distefano and Kelly 2016).

The assessment of the impacts of climate change on human welfare are generally performed by using integrated assessment models (IAMs), such as GCAM (GCAM 2012). IAMs are mathematical computer models that integrate both social and economic components with biogeochemical cycles to assess the resultant effect of greenhouse gas emissions. Economic losses are mainly determined by a damage function that relates temperature and precipitation variations to the economic effects across different hypothetical futures, also called Shared Socioeconomic Pathways (O'Neill et al. 2015). Compared to disaster risk models, IAMs are generally used to assess the effects of slow-onset changes, such as temperature increase, with few experiences on catastrophic risk (Bosello, De Cian, and Ferranna 2015; Pindyck and Wang 2013).

Old Issues and New Challenges: Modeling under Changing Conditions

Many studies have already highlighted the increase in value of global annual average losses from natural hazards (see for example Munich Re 2014). Evidence shows that, in the future, the increasing exposure and vulnerability of assets, economic activities, and population to natural hazards will continue contributing to the increase of global losses. Moreover, climate change will further exacerbate this trend. Unfortunately, the capacity of economic and financial risk models to reproduce systems' dynamics is still limited. High levels of uncertainty, particularly under changing conditions, still characterize the outcomes of the models. The recent critique of integrated assessment models (Pindyck 2013; Stern 2013)—echoed by the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC 2014)—voices a growing frustration with contemporary models reckoned too simple and arbitrary. Contemporary economic risk analysis and assessment practices could face comparable critiques. It remains the case that disaster risk assessments are rarely dynamic exercises and cannot represent the overall and interrelated systems' reaction to and recovery from a disaster, the multifaceted conditions of fast-growing economies, or changes in land use and the environment.

Looking Forward

Over the lasts decades, catastrophe models have made substantial improvements in their capacity to assess the physical damage of extreme weather and climate events. This success has contributed to the development of a number of financial instruments targeting disaster risk. Despite this accomplishment, our understanding of the full economic cost of disasters is still limited. Economic risk models can help to fill this gap, but if real-world policies and investments are to be based on them, they need to be more robust and reliable. Moreover, there is a need for tools that are affordable, credible, transparent, and open access, as well as tailored to specific perils and scales of analysis (regional to municipal). Recent experiences of model coupling have demonstrated the capacity of economic risk models to provide outputs at local scale. For example, Carrera et al. (2015) coupled spatial analysis and regionally calibrated CGE models to assess climate change effects on flood risk at regional level in Italy. For the same country, Pérez-Blanco et al. (2016) coupled a revealed preference model calibrated at local level and a regional CGE model to inform water resources management policies under drought conditions. Other models (CGE) have also been developed at municipal scale, for example to assess flood risk in São Paulo, Brazil (Haddad and Teixeira 2015). Recent efforts to add realistic behavioral features, through evolutionary methods such as agent-based modeling (Safarzyńska, Brouwer, and Hofkes 2013), network analysis, and supply chain principles (Rose et al. 2016), hold promise for improving models' capacities to capture systems' response in the aftermath of a disaster.

Better evidence of economic losses and ex post analysis of disasters' effects are needed to improve models' robustness, through calibration and verification. This need becomes more and more pressing under global change conditions. The ongoing efforts of the Directorate General for European Civil Protection and Humanitarian Aid Operations (ECHO) to promote a standardized European disaster loss database are steps in the right direction. With better disaster loss data, more improvements will surely come in the near future.

Bridging the gap between the disaster risk management and climate change adaptation communities will be key to improving our ability to assess and estimate the economic effects of disasters and climate change—with a specific focus on the scope and scale of analysis and consideration of the complexity of dynamic and interconnected systems.

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UR2016 participants spending time in the Expo area: Deepti Bhatnagar of RMSI (left), Stuart Fraser of GFDRR (middle), and Sushil Gupta of RMSI (right). Photo credit: Emanuele Basso.

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ESA is developing a new family of missions called Sentinels specifically for the operational needs of the Copernicus program.
Photo credit: European Space Agency.

Climate Change Plenary

Using Risk Information to Mitigate Climate Change Impacts—Challenges and Opportunities

Introduction

Climate change is one of the biggest challenges of the 21st century. It increases global vulnerability to natural disasters, and could push an additional 100 million people into poverty by 2030 (Hallegatte et al. 2016). Taking action to mitigate the impacts of climate change can be challenging, partly because the specific impacts are uncertain, and partly because forecasting what might happen in a specific location in a specific year is difficult. Furthermore, with rapid urban development and economic growth, global hazards are constantly in flux. This complexity requires a paradigm shift, from static assessments of today's risk to dynamic risk assessments that policy makers and business leaders can use to plan for the future.

To provide a spectrum of views on tackling climate change, we describe how three groups—the reinsurance industry, humanitarian donors and service providers, and space agencies—view efforts to integrate risk information into decision making. As providers of key information, these groups all play a role in how organizations and communities around the world will react to climate change risk. The discussion and case studies below suggest both how they comprehend risk and how risk communication can propel action.

Background

The *insurance and reinsurance industry* is in a unique position relative to climate change because uncertainty and risk are fundamental to its core business. Reinsurance companies engaged early with scientific institutions to assess climate change impacts and price risk appropriately; their models have included climate change as a factor of uncertainty for more than 25 years.

To understand the accumulation of risks posed by climate change, reinsurance companies look every few years at evidence of secular changes in climate that are increasing the level of hazard, such as increases in the frequency of disasters, and adjust their risk models accordingly. Firms convey this risk information through the price of the insurance contract. This price signal also reflects changes in human responses to climate change; for instance, failure to maintain flood barriers may cause an increase in price.

Humanitarian organizations provide life-saving postdisaster aid, but also understand that proactive, longer-term efforts to mitigate risk can save lives and money. The Red Cross Red Crescent Movement, for example, established its Climate Centre in The Hague to better understand climate change risks and in turn help vulnerable communities grapple with them. The movement has also established forecast-based financing initiatives and a Disaster Resilience Fund that invests in preparedness, training, logistics, supplies, and education to help communities understand and reduce climate change impacts.

As part of its humanitarian mission and more generally, the European Union (EU) has for many years anticipated the risks of climate change and used its considerable resources to address them. All budgets reflect climate issues, including those for humanitarian funds. This mainstreaming of climate change in the design of sector programs improves communities' resilience.

Space agencies provide roughly three-quarters of the information needed to understand the earth system information of climate change. These data are provided through a critical suite of 50 sensory and image-based parameters defined by the Global Climate Observing System as Essential Climate Variables. In addition to providing basic information to assess the progress of climate change, space agencies' priority is to look for indicators of change, of future risk, and of adaptation, and then to collaborate with other institutions to provide services to help local communities adapt to the known change of climate.

The Copernicus program, a partnership between the European Space Agency and the European Union, guarantees environmental monitoring services over the next 30 years. During this period, data on atmospheric chemistry and many of the parameters critical to understanding climate risk will be free and publicly available. The program guarantees the availability of the entire suite of environmental and climate data beyond 2030 by providing multiple copies of each series of spacecraft, launched in sequence over the coming years.

Imagine a hypothetical scenario: you are a humanitarian in an elevator with the minister of finance from a developing country, with 30 seconds to convince her of the need to act to mitigate the effects of climate change. What do you say?

Perspectives in Tackling the Impacts of Climate Change

Trust and Collaborative Reinsurance Models Build Resilience

Insurance penetration is low among unstable and poor countries, even though there are insurance and reinsurance products to solve some of the biggest economic obstacles those countries face. This contradiction arises in part because some individuals, communities, and governments believe that insurance could exacerbate financial hardship, despite evidence to the contrary. In fact, countries with high insurance penetration (60 percent or more) suffer much less after disasters than those with lower penetration, and experience almost no indirect disaster loss, such as business interruption (von Dahlen and von Goetz 2012). Disaster risk insurance has also been found to act as a mitigant to potential downgrades of sovereign ratings (Standard & Poor's Rating Services 2015).

Establishing trust with vulnerable populations—which is critical to the success of insurance products—requires partnership and collaboration. With this understanding, SwissRe has developed and invested in a collaborative process methodology called Economics of Climate Adaptation, and has completed 10 such projects with KfW in Asia and Latin America.

The Economics of Climate Adaptation is a collaboration with local stakeholders in which communities assess their own risks and a cost-benefit analysis is conducted—both to identify climate adaptation measures to reduce risks and to determine the benefits of averted losses. Communities can then potentially transfer their risk to reinsurance firms with the financial capacity to absorb it. Finally, the complete model is handed over to local stakeholders, allowing them to calculate the risk, costs, and benefits of future economic development, given the additional risk of climate change.

Village-Level Responses to Climate Change Matter

Imagine a hypothetical scenario: you are a humanitarian in an elevator with the minister of finance from a developing country, with 30 seconds to convince her of the need to act to mitigate the effects of climate change. What do you say?

You start with the fact that politicians' political survival depends on what goes on in the villages. You explain that detailed, sustained, village-led responses are needed. You say that when land and livelihoods are lost and villagers have nowhere to go, they will become a rural proletariat. The blunt truth is that without appropriate action, there will be not only crop failure, flooding, and an increase in disease-related deaths, but also other risks beyond the finance minister's remit. Villagers who lack food or livelihoods might join violent groups. You finish your pitch by mentioning how much more unpleasant it would be to receive an elevator pitch from one of these groups than from you.

In response, the finance minister from the developing country says she has already looked at the harvest figures, observed the global climate change systems, and understands how her country's demography as it relates to climate change may create a recipe for disaster. Along with the agriculture minister, the planning minister, and local humanitarian agencies, she has worked with the communities to devise detailed resilience plans. However, says the minister, development aid as it relates to climate change risk underestimates the risks to the underprivileged and is tied to infrastructure projects—the minister wishes she was able focus on vulnerabilities in the villages. This scenario gets to the heart of what is needed: government, international, local, development, and humanitarian actors working steadily together and focusing on village-level needs.

Ethiopia offers an example of a successful link between national and local disaster risk reduction. The government's social safety net program uses satellite imagery of different regions to observe rainfall and investigate the risk of a bad harvest, in dialogue with local tribe leaders. With El Niño kicking in, the effects of this planning are observable. Local-level risk awareness combined with supplementary foreign assistance has saved lives.

How to Use Space Agency Data: Show the Consequences

Many models of climate change focus on basic predictions, such as the probability of a two-degree temperature change in the next 30 years. But risk communication is more effective when it focuses on consequences and answers pressing questions about how the increasing likelihood of events will affect societies. Those models tell a more relevant, and more dramatic, story.

Politicians, businesses, and those working in the humanitarian and development sectors need information about the likelihood of disaster events to decide how to act. Consider the 2003 heat wave in France that caused 30,000–70,000 excess deaths. As the climate system stood in 1900, that heat wave was a 1-in-100-year event. In 1990, it was a 1-in-50-year event. By 2005, it was 1-in-5. Insurance risk is modeled in terms of likelihood of events, and if climate projections used the same method, the consequences of climate risk would be clearer.

Moreover, this approach aligns with the increasingly complex questions that space agencies and other organizations are addressing about the interaction between physical systems and society, demography, and demographic shifts such as migration. For example: To what extent is the crisis in Syria related to climate change? In 2006–2007, a major drought forced 2–3 million people in Syria to move to cities. This mass migration placed cities under intense strain. Would Syria be in its current position had the global community acted in 2006? What would be the consequence for Europe if a similar climate event were to occur in the Sahel region? What might that lead to in terms of economic migration? The best models demonstrate the increasing likelihood of disaster and catastrophe events, and link them to the consequences those events will have on our lives.

Challenges

A number of challenges confront institutions and communities wishing to mitigate climate change impacts:

- *Most sectors have difficulty deciding how to act.* The development and humanitarian sectors do not share a model for responsible action to balance saving lives with risk-informed development; politicians have constraints on their attention and budgets; and private companies can have difficulty finding the right information to guide investments to safeguard against future potential risks.
- *Insurance coverage is low among the most vulnerable.* Households in poor countries tend to rely on agriculture and other income sources that are vulnerable to hazards, but these households are at the same time far less likely to have insurance coverage.
- *Stakeholders do not trust or communicate with one another.* Communities, donors, humanitarians, development agencies, private industry, and government could potentially work together. Despite the wealth of data, innovation, and political will, however, many often feel that "others" must do more.
- *Communities do not know how to act.* Communities can often anticipate the next disaster, but are hampered in preparing because they lack needed tools and do not know which national or international organizations to contact for help.
- *Communicating risk can be difficult.* Modelers still struggle to communicate risk effectively. Models showing a 0.3 degree increase over 10 years, for example, may produce nothing more than a shrug of the shoulders, even when such a change can have serious consequences.

Recommendations

- *Bring the humanitarian and development communities together.* This step would encourage humanitarian organizations to focus on prevention and preparedness and allow them to share their substantial on-the-ground knowledge of risks with development actors. This in turn would promote more risk-informed development.
- *Improve the regulatory framework and collaborate with business.* The opportunity exists to take advantage of businesses' efficiency, technological innovations, and customer demand for products and services that promote resilience. Businesses should be encouraged to see the first-mover advantages in climate change scenarios. Unilever's carbon-neutral manufacturing, for instance, makes the company enormously resilient—independent of changes in energy policy and energy costs.
- *Focus on good governance.* Efforts to mitigate climate change impacts will be in vain without good and reasonably uncorrupt institutions. This is a vast agenda but crucial.
- *Create partnerships for anticipatory assistance and innovative modeling approaches.* Thoughtful partnerships should be formed to develop new products and services to meet the needs of vulnerable populations. Space agencies have data; insurance companies have expertise in cost-benefit analysis; and humanitarian actors have community-level knowledge.
- *Push for insurance coverage for the most vulnerable.* Reinsurance companies can help reduce exposure. For instance, they can insure countries at risk, communities living in floodplains, and agricultural companies in regions where drought risk is significant.
- *Communicate risk information effectively.* Better communication can be achieved by methods that look at consequential events such as the likelihood of flooding or cyclones, using value-added information such as demographic and social shifts. This approach may entail the difficult conversations that can sway politicians and other power brokers to act on risk.
- *Communicate in schools and capitalize on the skills of youth.* Getting young people to understand the risks they face—not as victims but as

problem solvers—is crucial. The Red Cross Red Crescent Movement and the European Space Agency have programs focused on educating youth, but more can be done in this area.

- *Address the details and listen to community needs.* Viable development means bringing development into villages and addressing village-level details. This step requires placing trust in communities, which means giving local civil society and community leaders a chance to show what they do or do not understand about their own risk.
- *Join the One Billion Coalition for Resilience (1BC).*[1] This coalition seeks to bring one billion people together both to look at threat-specific resilience and to build trust and understanding among coalition members. Trust building is key; if communities do not trust the source of information, they will not believe the information.
- *Resolve to act now and in the future.* The world needs both to adapt to the consequences of change and to prepare for the changes that will happen in the future. This is not a trade-off.

1 See the One Billion Coalition for Resilience website at ifrc-media.org/interactive/one-billion-coalition.

Conclusions

To address the challenges posed by climate change, international agreements matter but are not enough. Stakeholders must seek sometimes unexpected partnerships; they must build trust at all levels, from the community level to the international; and they must bring people together to share understanding and knowledge, to plan, and to act.

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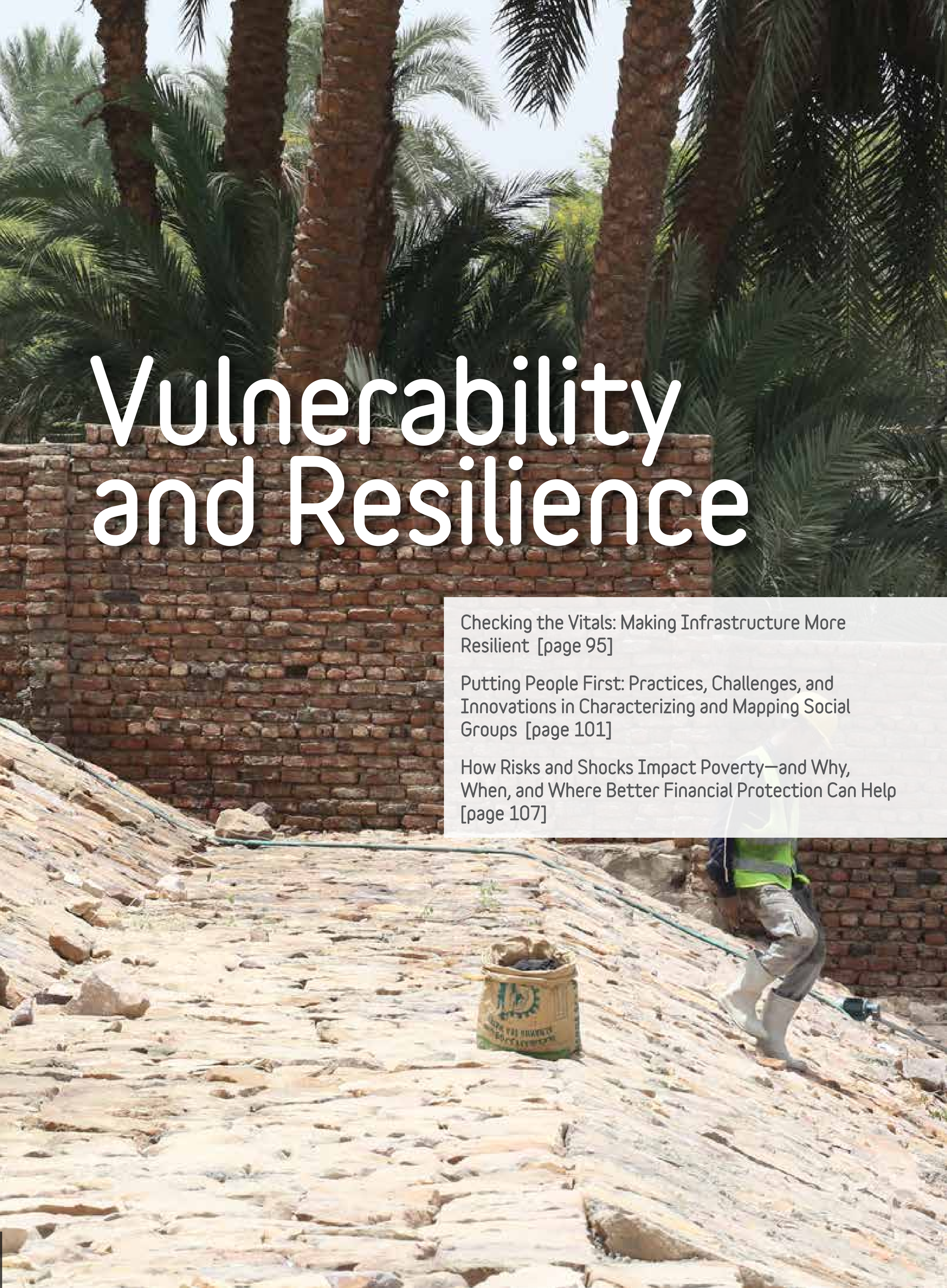
Jemilah Mahmood addresses the audience during the climate change plenary with (from left) John Roome, Esther Baur, Stephen Briggs, and Claus Haugaard Sørenson. Photo credit: Emanuele Basso.

Construction workers in Luxor, Egypt, build stronger river banks along the Nile River. Photo credit: Dominic Chavez/World Bank.



Vulnerability and Resilience

Checking the Vitals: Making Infrastructure More Resilient

Tom Roche, FM Global

Introduction

The scene after catastrophes like a violent storm, powerful earthquake, or devastating fire is all too familiar. People offer comfort and shelter to those in need and tend to the injured. This initial reaction is quickly followed by efforts to bring critical infrastructure back on line, starting with the vital elements of power and water. Those involved in such restoration efforts know that the immediate effects of a disaster can be intensified should they fail.

The long road to recovery after a catastrophe depends on having critical infrastructure in place to support the process of rebuilding the community and helping industry to recover. But the best time to strengthen this infrastructure is before a catastrophe strikes. The goal should be to make the infrastructure resilient—resistant to collapse and engineered to recover quickly.

Background

Infrastructure systems around the world are under increasing pressure—from growing populations, growing urbanization, and changing demands. These pressures play out differently, however, in developing and developed countries.

In the developing world, strong, effective systems for power and water infrastructure are needed to facilitate economic growth and to sustain burgeoning and concentrating populations. One challenge to providing these systems is often simply time, as populations grow and land is developed rapidly. A second challenge is finding the resources to prepare and deliver this infrastructure when budgets are already stretched. Compounding both these challenges is the fact that these regions are particularly susceptible to natural disasters due to their geographies. For example, developing Asian and Pacific countries incur more than $50 billion in disaster costs each year (ADB 2013).

In the developed world, where there are complex systems of ownership and funding for infrastructure, aging systems present their own challenges—specifically ongoing maintenance, continued performance, and large financial decisions around their renewal. According to the American Society of Civil Engineers, there is a growing infrastructure investment gap in the United States. Failure to close this gap will impact the ability to update and expand U.S. infrastructure, which in turn will cause a $4 trillion loss in gross domestic product by 2025 (ASCE 2016).

In response to these pressures we are seeing unprecedented interest and investment in infrastructure globally. Estimates place the need for global investment up to 2030 at $57 trillion (McKinsey Global Institute 2013). The challenge for governments, their agencies, and businesses is to ensure that these investments build the concept of resilience into their projects.

Box 1: How Resilience Depends on Hazard Information

The 2007 flooding in the United Kingdom highlighted the vulnerability of the water and power networks. Inundation of a water treatment facility left 350,000 people without potable water for 17 days, and a flooded substation left 42,000 people without power. The government review that followed called for better flood information and more investment by utility companies to protect key infrastructure sites (Pitt 2008). In response, a number of agencies have collaborated to improve the understanding of flood hazard and the exposure of critical infrastructure in the United Kingdom.

Following the 2011 earthquake in Christchurch, New Zealand, other cities sought to understand the impact of an earthquake on their own infrastructure. In Wellington, groups representing local government and utility providers collaborated to define the likely events that might occur and determine the infrastructure recovery times (Wellington Lifelines Group 2012). They concluded it would take 20 to 65 days before power and water utilities would be recovered across the city's suburbs. This work has helped to promote action to improve the resilience of the city's infrastructure.

The Vitals

When looking to build resilience into projects for power and water, several elements are vitally important: hazard assessment, codes and standards, operations and maintenance, and emergency response plans.

Hazard Assessment

Hazard assessment provides crucial information for siting of infrastructure and for identifying and assessing vulnerabilities. In some areas of the world, this will mean mapping hazards for the first time. But even in areas that have been mapped, it is important that potential hazards are well understood.

Ensuring that infrastructure is resilient to hazards means taking account of the whole interconnected system or network. The behavior and performance of the network when subject to a particular hazard needs to be modeled; the same is true for the behavior and performance of the network's individual components. What will be the wider impact if this particular pipe bridge collapses in a flood, this power plant drops offline in a storm, or this reservoir is breached by an earthquake? In this way key nodes as well as critical and alternative supply routes can be identified and analyzed. This information can help to set operational parameters and inform emergency planning in the future.

To meet the challenge of a hazard-resilient infrastructure, governments need the right hazard information (geological, meteorological, etc.) and sufficient technical expertise to properly identify and assess vulnerabilities (see box 1). Often this requirement necessitates partnering with a spectrum of professionals who have expertise in a full range of hazards and understand their consequences for the infrastructure. Increasingly, open source models and global collaborations (public-private-academic partnerships) are changing the landscape of hazard assessment. Once the hazard is assessed, the performance criteria and specifications can be adapted to suit the defined hazard.

Codes and Standards

The use of strong codes and standards is key to delivering a resilient infrastructure. Codes and standards are developed and delivered by a variety of institutions, including industry, trade associations, and government agencies. Their purpose is to help ensure minimum criteria are met for the design, construction, operation, and ongoing maintenance of the infrastructure elements. When infrastructure developers know how codes and standards are developed, and know their intended outcomes, they gain a deeper understanding of how to design and build resilient facilities.

Based on hazard information, codes specify the materials, capacities, redundancies, and safety factors for the desired resilient infrastructure. For critical buildings and equipment, there is often a need for the design to include an increased safety factor, or even go beyond the code should it fail to offer the appropriate level of resilience.

The importance of strong codes and standards can be seen when we compare the performance of infrastructure and buildings in two different events—the earthquakes in Chile and Haiti in 2010. In response to damaging earthquakes in the 1960s, Chile had developed and implemented a complete scheme of seismic building codes and standards. Haiti had limited building codes and no seismic standards for buildings. The death tolls highlight this difference: more than 200,000 were people killed in Haiti and fewer than 1,000 in Chile. Although both events were catastrophes, the use of strong seismic codes and standards in Chile helped to lessen the impact.

Enforcement plays a key role in any code's effectiveness. Deviations from code—whether using an alternative or falling short of the standard—can lead to delivering a system or structure that has increased vulnerabilities. Analysis of the 1999 earthquakes suffered in Izmit, Turkey (USGS 2000), and Jiji, Taiwan (the so-called 921 earthquake) (SSC 2000) highlights the importance of enforcement. Both areas had building codes in place that acknowledged the local seismic hazard, but there were gaps in enforcement for new buildings. In both areas, the buildings and infrastructure not built to code performed badly. Locales seeking to enforce codes over the life of the infrastructure need individuals with the right skills and expertise as well as institutions with the required capacity and integrity.

Operation and Maintenance

Operation and maintenance of infrastructure is as important as its physical attributes. From its first minutes of operation any system will start to degrade; this is perfectly normal. Appropriate maintenance and carefully managed operation are both needed to ensure that the desired level of performance continues to be delivered. Improper operation or operational changes can make systems more vulnerable, as well as slower to respond and recover after disruption. Systematic training and management of change is essential to avoid these issues. The potential effects of improper operation and maintenance are highlighted in box 2.

Operators and regulators must have the expertise, capacity, and integrity to ensure that codes, standards, and best practices are followed. There is always a balance to be struck between appropriate maintenance, operational efficiency, and costs, but the desired resilience needs to be given importance in this equation to ensure that it is not compromised.

Emergency Response Plans

Strong designs and equipment, suitable locations, and appropriate operation and maintenance can all help to minimize the impact on infrastructure. The true test

For critical buildings and equipment, there is often a need for the design to include an increased safety factor, or even go beyond the code should it fail to offer the appropriate level of resilience.

Box 2: Why Operation and Maintenance Matters

The largest electricity blackout in North America occurred in August 2003, when a combination of events and a 345 kV power line tripping due to tree contact led to a cascade failure. The blackout, which impacted over 50 million people, was investigated by a joint task force from Canada and the United States (U.S.-Canada Power System Outage Task Force 2004). According to the task force report, operational issues with vegetation clearance and alarm systems and an inadequate understanding of the network were contributing factors; among many things, the report called for establishing and enforcing reliability standards.

comes in an emergency or when the anticipated hazard is realized—the earthquake strikes, the windstorm hits, or the floodwaters rise. Having a plan is a good start, but to ensure that operations continue with minimal interruption, an operational culture that trains, tests, and prepares for these events is essential. There must be no question of who will watch the weather and decide when to shut the power off during a flood or when to swap to an alternative system to maintain the stability of the power supply.

As the example of the North American blackout shows (box 2), it is essential to train operators so they thoroughly understand the infrastructure and can make appropriate decisions when they matter. Those overseeing critical infrastructure must ensure that businesses and public facilities have emergency plans in place and well-trained operators who can help to carry them out.

Case Study in Resilient Infrastructure: Tokyo Waterworks Bureau

Japan has had extensive experience with large and devastating earthquakes. Following the 2011 Tohuku earthquake, the Tokyo Waterworks Bureau evaluated the potential impact of an earthquake on the city's water supply network. This analysis highlighted potential damage to critical water treatment facilities and disruption of supply to key zones, and it led to a multiyear plan to improve the resilience of the water infrastructure supplying the city. More specifically:

- The analysis highlighted the need to improve the resilience of the connection from the Tome and Arakawa Rivers, which provide water for 80 percent of Tokyo's needs, by adding a second water intake.
- To improve the system's ability to treat raw water coming from the Tome and Arakawa Rivers, a second raw water connection between the main water treatment facilities of Asaka to Higashimurayama is planned—via an earthquake-resistant 2,000 mm pipe.
- The performance of key elements of the water supply network—reservoirs, pumping stations, etc.—was evaluated against the expected seismic event, and an active program of upgrading and retrofitting to the latest earthquake standards is now being undertaken.
- Using the latest standards, a 10-year program is under way to promote earthquake-resistant joints on key pipe networks.
- Emergency training has been set up with the local community to ensure that residents understand plans for water in the event of an earthquake. This training also allows for testing of the emergency facilities that have been put in place for permanent and temporary water supplies, and provides valuable feedback so plans can be improved.

Conclusion

Deliberately working to address the vital elements in power and water infrastructure can increase resilience and help to minimize potential interruptions in supply. As efforts are made to deliver the infrastructure needed to meet the growing demand across the globe, there is a great opportunity to utilize available expertise to ensure that resilience is built in. No single agency is responsible for meeting this goal, but it can be met when various government, industry, and private sector experts work collaboratively.

While infrastructure can't always emerge unscathed from the worst-case catastrophe, the majority of extended power and water interruptions are preventable, not inevitable.

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Child refugee standing in front of his village, which was destroyed by the Mount Merapi eruption in Klaten, central Java, Indonesia.
Photo credit: © Akbar Solo | Dreamstime.com.

Putting People First: Practices, Challenges, and Innovations in Characterizing and Mapping Social Groups

Jianping Yan, United Nations Development Programme

Introduction

Disasters impact different people differently. The socially vulnerable are most at risk from disasters and consequently also suffer most from their impacts. The assessment of disaster impacts on vulnerable population groups is now possible; however, we do not yet systematically quantify the social dimensions of vulnerability or integrate these aspects in disaster risk assessments. The discussion below looks at how vulnerability is currently understood, describes some of the challenges involved in better understanding vulnerability, and proposes a framework for integrating social vulnerability assessment within a disaster risk assessment.

Background and Concepts

Social vulnerability does not have a single uniform definition. Five typical definitions of social vulnerability can been found in the literature:

1. Social vulnerability refers to *potential harm to people*. It involves a combination of factors that determines the degree to which someone's life and livelihood are put at risk by a discrete and identifiable event in nature or society.
2. Social vulnerability refers to the *characteristics of a person or group* in terms of their *capacity to anticipate, cope with, resist, and recover* from the impact of a natural hazard (Wisner et al. 2004).
3. Social vulnerability refers to the *resilience of communities* when confronted by external (natural or man-made) stresses on human health. Reducing social vulnerability can decrease both human

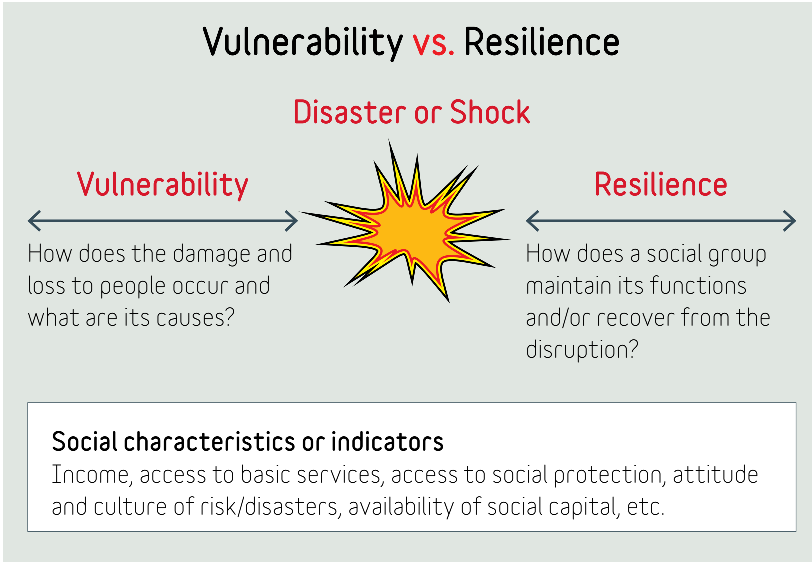
suffering and economic loss.[1]

4. Social vulnerability refers to the *inability of people, organizations, and societies to withstand adverse impacts* from multiple stressors to which they are exposed. These impacts are due in part to characteristics inherent in social interactions, institutions, and systems of cultural values.[2]

5. Social vulnerability refers to the *susceptibility of social groups to potential losses* from hazard events (Hewitt 1997).

These definitions reflect a number of critical issues in the understanding of social vulnerability. First, they mix notions of social vulnerability and resilience. For example, the frequently cited second definition seems more about societal resilience than social vulnerability, while the fourth definition simply includes the notion of resilience as part of social vulnerability. But while they are related, the concepts of social vulnerability and resilience address different characteristics of social groups. Social vulnerability addresses the susceptibility of social groups to potential losses caused by hazard events, whereas resilience reflects the ability of social groups to deal with a disaster or shock. Second, the concept of social vulnerability and resilience is context- and hazard-specific. For example, social groups in one community might be vulnerable to earthquakes, but not necessarily vulnerable to floods. Even within the same community, the vulnerability of social groups may differ depending on groups' actual exposure. Third, social vulnerability should be distinguished from the specific needs of socially vulnerable groups following a disaster, which arise out of the crisis or disaster itself and are relatively short term.

Figure 1. Vulnerability as the flip side of resilience.



The correct understanding of the concepts of vulnerability and resilience is critical. As illustrated in figure 1, vulnerability relates to how certain social groups suffer damage and loss; the study of vulnerability aims to explain what makes these groups vulnerable. Resilience on the other hand relates to how social groups maintain their functions or recover from a disruption. The study of resilience uses the same set of social characteristics or indicators as the study of vulnerability (box 1).

The study of social vulnerability should explain how certain social characteristics contribute to people's worsening situation during a disaster. It should explain, for example, why over 70 percent of the dead in Hurricane Katrina were over the age of 65, and why African Americans suffered a disproportionate number of deaths relative to whites and to their local population numbers; why of the 300,000 people killed in the 2004 Indian Ocean tsunami, 240,000 were women and children; and why in the Great East Japan earthquake of 2011, more than half (56 percent) of the victims were aged 65 or older.

To some extent, social vulnerability is the socioeconomic and political root cause of risk and disaster. For example, the elderly are fragile, but age alone does not create vulnerability; vulnerability also

[1] Agency for Toxic Substances and Disease Registry, Social Vulnerability Index, http://svi.cdc.gov/.

[2] Wikipedia, "Social Vulnerability," https://en.wikipedia.org/wiki/Social_vulnerability.

Box 1: Dimensions of Social Vulnerability and Resilience

1. Level of poverty
2. Access to resources such as information, knowledge, and technology
3. Access to political power and representation (marginalization, exclusion)
4. Social capital including social networks and connections
5. Social beliefs, customs, and attitude in response to risk or disasters
6. Vulnerable residential settings (i.e., weak structure, poor protection, poor maintenance, etc.)
7. Presence of frail and physically limited individuals
8. Access to critical services such as communication, transportation, power supply, water supply, sanitation, etc.

Source: Adapted from Cutter et al. 2003.

arises from society's failure to recognize that limited mobility impedes timely evacuation. When disaster managers and political leaders fail to design warning systems that reach people who are deaf or to provide paratransit systems to evacuate wheelchair users, society bears responsibility for the consequences. Social vulnerability thus results from processes of social inequality and historic patterns of social relations that manifest as deeply embedded social structures resistant to change.

Challenges

The study of social vulnerability faces at least four distinct challenges:

1. How to select indexing or analytic approaches to social vulnerability assessment

Most studies of social vulnerability use an index-based approach to profile the social composition of a jurisdiction. Social groups categorized by race/ethnicity, language/literacy, education, etc. are used as proxies for social vulnerability. The index-based approach is generally not linked to the actual exposure of the social groups to different hazards. Most studies aim to compare the relative vulnerability of different jurisdictions, and do not address why certain groups are at risk or how their situation will worsen after a disaster.

However, the study of social vulnerability should be a diagnostic process that aims to identify the root causes of the risks associated with socially vulnerable groups and the implications of the risks. Policy makers and emergency/disaster management practitioners need evidence of social vulnerability. Efforts to characterize social groups' vulnerability should do the following:

- Categorize social groups in terms of the context
- Identify the exposure of social groups to specific hazards
- Clearly understand the social vulnerability, societal resilience, and specific needs of these social groups relative to disasters
- Identify options to reduce the underlying conditions of the risks they face

2. How to categorize socially vulnerable groups in terms of context

The first step in social vulnerability study is to understand the composition of the society, that is, to categorize social groups in a proper and meaningful manner. Common classifications—race/ethnicity, gender, age, etc.—are intrinsically connected to opportunity, inequality, and oppression, and thus reflect social vulnerability in any given society. Disaster situations can expose these systems of stratification and vulnerabilities in many ways.

But classification needs to recognize that social groupings are complex and context-specific, i.e., the groups identified as socially vulnerable are different in different countries. For example, while developed countries may consider the elderly a socially vulnerable group, in developing countries, children and youth are especially vulnerable. The 2013 Haiyan Typhoon, the deadliest rapid-onset disaster the Philippines has experienced, killed 6,000 people and affected 6 million children. Understanding why Typhoon Haiyan impacted working children (or child laborers) and adolescents in the country is crucial; the root causes of their differential vulnerability, resilience, and needs must be considered in developing disaster risk reduction solutions.

3. How to systematically collect social data and keep them current

Social vulnerability is dynamic and its study generally requires four types of data: census data, predisaster and postdisaster studies, data created within the community (such as actual information on households and their income, population mobility, etc.), and surveys with special purposes. National census data can be used to categorize socially vulnerable groups, while the other types of data have to be collected and updated from time to time. How to keep all the data current is a big challenge to the study of social vulnerability.

To address this challenge, the Organisation for Economic Co-operation and Development (OECD) established the Partnership in Statistics for Development in the 21st Century (PARIS21), an international consortium that seeks to build statistical capacity in developing countries. PARIS21 engages national statistical systems in coordinating the systematic collection and extraction of data on spatially and sociodemographically disaggregated characteristics.

4. How to use information on social vulnerability

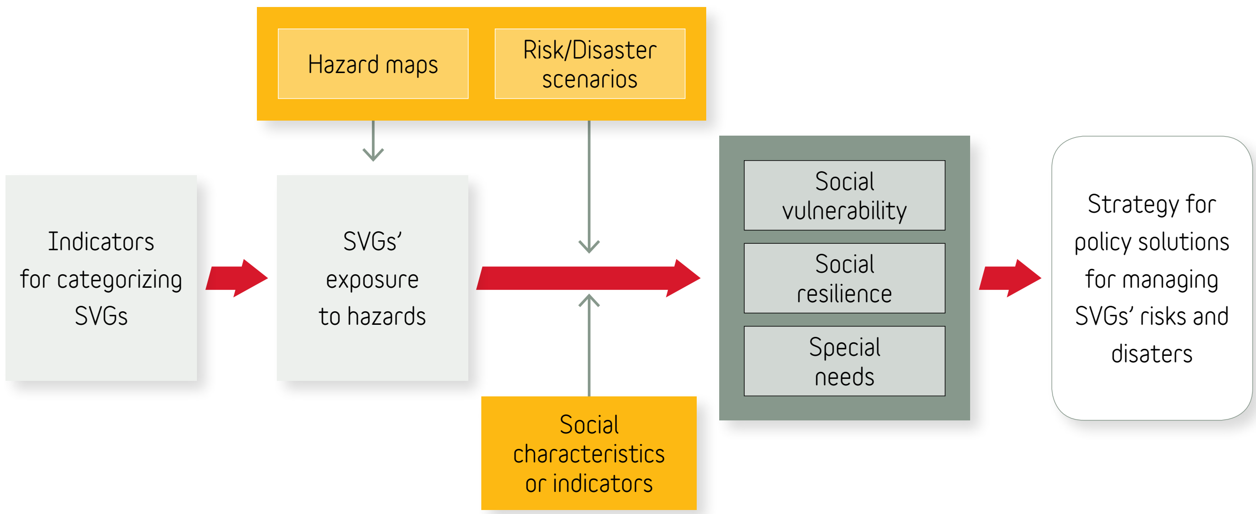
Most studies of social vulnerability remain academic and produce outputs that are not applicable to actual decision making. On the other hand, policy makers and disaster risk reduction practitioners urgently need evidence-based data and information on social vulnerability and resilience for developing context- and hazard-specific social protection mechanisms (Costella 2015).

Recommendations

To integrate social vulnerability assessment within a disaster risk assessment, a contextual framework is proposed for characterizing and mapping socially vulnerable groups, as shown in figure 2. Assessing social vulnerability should be a four-step process that is based on the key outputs of a disaster risk assessment, such as hazard maps, and plausible risk and disaster scenarios, and that aims to identify the root causes that put people at risk:

- **Step 1:** Categorizing and identifying socially vulnerable groups in terms of context
- **Step 2:** Mapping the exposure of the targeted groups to different hazards

Figure 2. A contextual framework for characterizing and mapping social vulnerability and resilience to disasters in a disaster risk assessment process.



Note: SVG = socially vulnerable group.

- **Step 3:** Assessing the social vulnerability, resilience, and special needs of these groups to specific disaster scenarios, in terms of a set of social indicators (as in box 1)
- **Step 4:** Identifying context- and hazard-specific strategy and policy solutions to mitigate the vulnerability and resilience of these groups.

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Attendees participate in a mapping exercise during the UR2016 Focus Day event, "Let's Shake Your Community—Earthquake Hazard Mapping Approach for Community Resilience." Photo credit: Andrea Basso.

Cattle for sale at Babile, Ethiopia, one of the largest livestock markets in the Horn of Africa. Photo credit: © Ilia Torlin | Dreamstime.com.

How Risks and Shocks Impact Poverty—and Why, When, and Where Better Financial Protection Can Help

Daniel Clarke, World Bank Group
Johanna Avato, World Bank Group

Background and Concepts

Recent data indicate a sharp rise in natural disasters over the last 50 years (figure 1). Despite poverty declining on average, many people are only one disaster away from poverty. Tropical Storm Agatha (2010) increased poverty 14 percent in Guatemala, for example, and over half the rural population in Afghanistan, India, Lao People's Democratic Republic, Malawi, Uganda, and Peru have reported exposure to one or more recent shocks, with natural disasters cited as the primary culprit (Baez et al. 2016).

Direct financial loss from natural disasters reached an average of $165 billion per year during 2002–2012, with losses exceeding $100 billion in six of those years (Clarke and Dercon 2015). Disaster risk finance aims to increase the resilience of vulnerable countries to the financial impact of disasters as part of a comprehensive approach to disaster risk management. By increasing resilience, disaster risk finance offers the promise of protecting against poverty and promoting development.

Yet empirical evidence showing whether this approach actually works in practice is only emerging. Such evidence is key to better guiding investments in sovereign disaster risk finance programs, to maximizing their expected impacts, and to ensuring that public investments deliver value for money.

It is also key for understanding the relationship between natural hazards and poverty: better financial protection might dull

Source: D. Guha-Sapir, R. Below, and Ph. Hoyois, EM-DAT: The CRED/OFDA International Disaster Database, Université Catholique de Louvain, Brussels, Belgium, www.emdat.be.

the impact of natural hazards on poverty, and hence change the nature of the poverty risk profile significantly.

The Disaster Risk Financing and Insurance Program, a joint initiative of the World Bank Group's Finance and Markets Global Practice and the Global Facility for Disaster Reduction and Recovery, has attempted to improve precisely this evidence base through its Disaster Risk Finance Impact Analytics Project. This project is supported by the UK Department for International Development's Humanitarian Innovation and Evidence Programme, and brings together the practices of catastrophe risk modeling, insurance, and disaster risk management with academic disciplines ranging from actuarial science and financial economics to public finance, social protection, microeconomics, development economics, and behavioral economics.

The Disaster Risk Finance Impact Analytics Project has succeeded in bringing new insights to the relationship between natural hazards and poverty. For example, work carried out under the project by de Janvry, Ramirez Ritchie, and Sadoulet (2016) finds that drought insurance payouts to Mexican farmers (made possible by disaster risk financing through the CADENA program) increase farmers' income by 38 percent and their consumption by 27 percent. Evidence on the magnitude of the total economic benefit is offered by De Janvry, del Valle, and Sadoulet (2016), who show that reconstruction of infrastructure assets (made possible by disaster risk finance through Mexico's FONDEN program) contributes on average to a 2–4 percent increase in postdisaster local economic activity.

The project also developed and then applied a methodology to quantify the costs of different combinations of budgetary and financial instruments used to finance disaster response (Clarke, Coll-Black, et al. 2016; Clark, Cooney, et al. 2016; Clarke, Mahul, et al. 2016). The approach results in a simple formula to capture the opportunity cost of risk-financing strategies and to help decision makers choose the least-cost approach.

Better financial protection might dull the impact of natural hazards on poverty, and hence change the nature of the poverty risk profile significantly.

Case Studies

The case studies described below—carried out by experts from academia, government, and the private sector—illuminate the relationship between extreme natural events and poverty, and provide evidence on whether predisaster financial decisions can change this relationship, dulling the impact of disasters on the vulnerable.

Catastrophe Risk Modeling and Economic Analysis of Vulnerability to Poverty in Ethiopia

Catherine Porter and Emily White present evidence from Ethiopia that brings together two strands of research that have thus far been developed independently: catastrophe (cat) risk modeling (figure 2) and economic analysis of vulnerability to poverty. This approach seeks to take advantage of the power that probabilistic cat risk models could have if applied to the assessment of household poverty outcomes. The challenge in applying cat risk models in this way is quantifying the relationship between hazard and outcome in a poverty context—the vulnerability module in a cat risk model. The researchers attempt to derive such vulnerability relationships for the impact of drought on households in Ethiopia; they ask whether a relationship can be derived between drought and household consumption that has internal and external validity and, if so, whether it can help (1) model risk (in a probabilistic framework) and (2) shed light on the benefits of interventions, including early response.

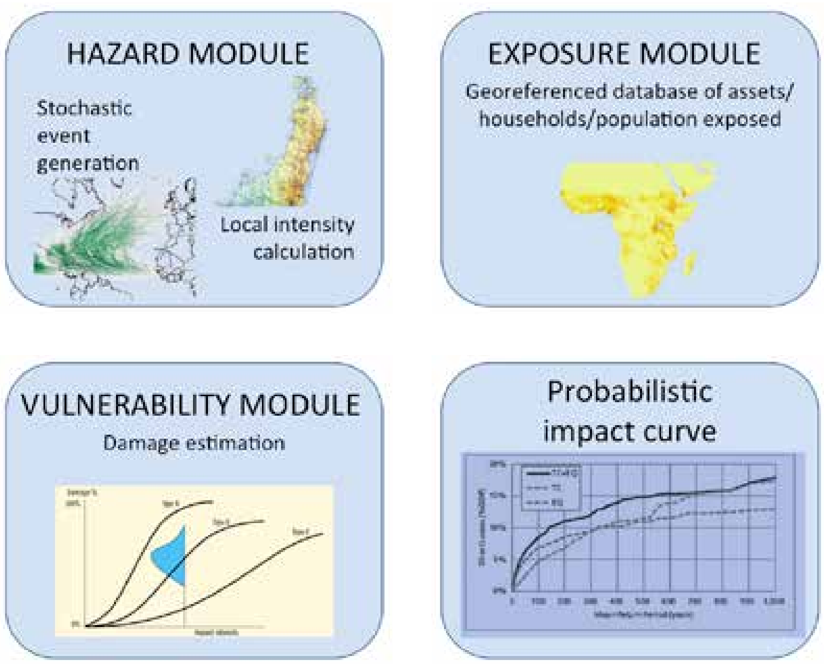
This study finds that the impact of drought is significant; for every 10 percent worsening of the drought, consumption falls on average by 2 percentage points. The results also reveal that access to a safety net (Ethiopia's Public Safety Net Programme) mitigates the drought impact by 0.5 percentage points—that is, households with access to the program experience a 1.5 percent decrease in consumption rather than a 2 percent decrease. The results suggest that the relationship between drought and consumption is fairly homogeneous and stable, so that it is possible to conclude (with caveats) that the derived drought-poverty relationship demonstrates some level of external and internal validity. Therefore, this relationship could form the basis of a vulnerability module in a catastrophe risk model.

Rainfall Index Insurance in India

The design of financial protection against shocks matters significantly for poverty reduction. Research

Figure 2. Probabilistic cat risk modeling modules and sample output

The hazard module shows historical cyclone tracks for generating stochastic events (from the United Nations Environment Programme Global Resource Information Database, UNEP GRID) and ShakeMap of the Tohoku earthquake for local intensity (from the U.S. Geological Survey). The exposure module shows population density (from UNEP GRID). The vulnerability module shows vulnerability curves for damage estimation (from CoreLogic's EQECAT platform). The probabilistic impact curve is for earthquake and tropical cyclone (from the Pacific Catastrophe Risk Assessment and Financing Initiative).

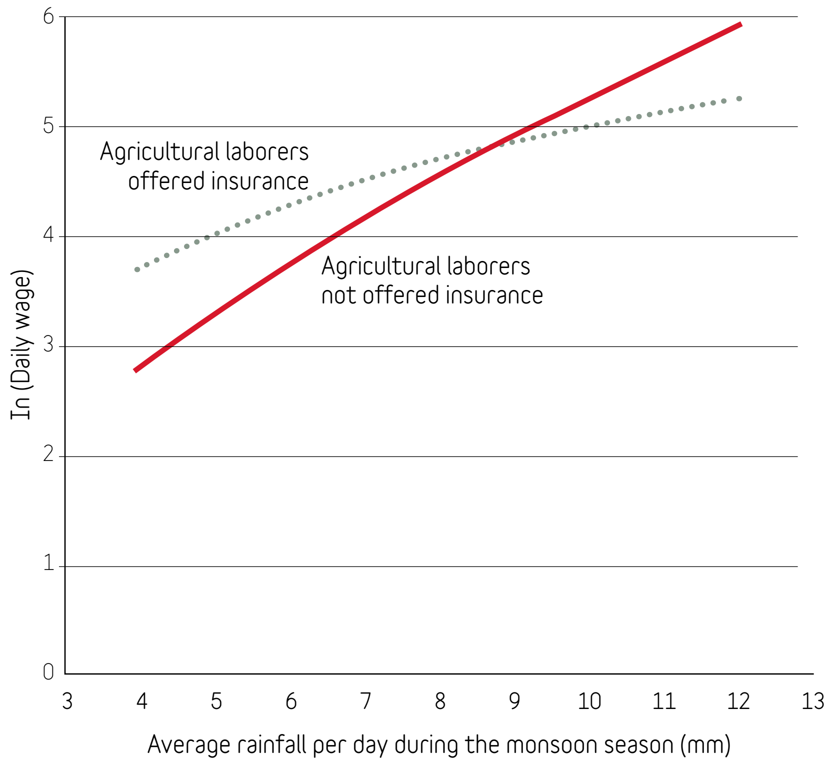


Source: Porter and White 2016.

by Javier Baez analyzes the welfare effects of a rainfall index insurance product offered to Indian farmers. Because index insurance products have novel features but may also have unintended consequences, properly evaluating their welfare effects requires moving beyond effects on the treated population and determining the general-equilibrium effects on both wage levels and volatility. In fact, the insurance may change risk-taking behavior and hiring practices by cultivators, and in turn affect the output and wages of landless laborers who make up a sizable proportion of the world's impoverished population. Baez finds that output becomes more sensitive to rainfall for insured farmers, and that output is actually lower for the insured than the uninsured in the lower half of the rainfall distribution. Hence harvest labor demand may also be lower in the low state for the insured cultivators.

Figure 3 plots the estimated insurance treatment effect on labor demand across the entire rainfall distribution in the sample. Labor demand by insured cultivators is statistically significantly higher (relative to the uninsured) for almost all positive rainfall shocks. The study also finds that marketing insurance to landless laborers reduces the sensitivity of wages to rainfall.

Figure 3. Estimated insurance treatment effect on labor demand.



Source: Mobarak and Rosenzweig 2014.

Index-Based Livestock Insurance in Kenya and Ethiopia

Studying the impacts of social protection programs on poverty can help in developing evidence-based policy recommendations. Focusing on results from an index-based livestock insurance (IBLI) product, which covers drought-related mortality and morbidity risks for pastoralist livestock in Kenya and Ethiopia, Andrew Mude shows that insurance has a beneficial impact on a range of socioeconomic outcomes:

- *Herd mortality risk*. Purchasing IBLI increases herd survival rates by considerably reducing the risk of catastrophic loss, and the majority of households are better off as a result.
- *Livestock productivity and household income*. IBLI coverage increases investments in maintaining livestock through expenditures on veterinary care, increases income from milk, and results in reduced herd sizes (consistent with precautionary savings).
- *Postdrought coping*. IBLI improves postdrought coping. After the catastrophic 2011 drought, there was a 36 percent reduction in the likelihood of distress livestock sales overall, and a 64 percent reduction among modestly better-off households. In addition to this, there was a 25 percent reduction in the overall likelihood of reducing meals as a coping strategy, and a 43 percent reduction among those with small or no herds.
- *Welfare*. Households purchasing IBLI showed reduced child malnutrition, had higher incomes per adult, and felt generally

A farmer sorts tomatoes in Ethiopia. Photo credit: World Bank.

more at ease and satisfied.

Overall, the evidence identified IBLI as a cost-effective social protection tool. Yet positive IBLI impacts do not necessarily justify investing scarce development or social-protection funds in insurance products; to know whether they do, it is necessary to understand the opportunity cost relative to the interventions.

Impact of Hurricanes on Household Poverty in Jamaica

There is a general understanding that the impact of hurricanes on household poverty is negative, but little consensus on to what degree. Research by Eric Strobl uses household panel data from Jamaica, including detailed information on consumption and expenditure as well as on location and buildings, for 9,500 households from 1990 to 2012. Although the findings support a negative impact of hurricanes on consumption per capita, the cross-sectional data overstate the impact; the effect lasts only one year and is not very large. Several explanations are possible for this, including the possibly poor damage proxy and households' use of informal insurance and budget reallocation mechanisms (such as receipt of remittances).

Conclusions

The case studies described here suggest some interesting conclusions and possible further research:

- Financial protection can help to increase financial resilience against natural disasters, but the design of products is critical. For example, basis risk in agriculture insurance products reduces their value.
- While essential for answering questions about shocks, data collection can be challenging, as shocks by their nature are unpredictable.
- The insurance industry has an established framework for assessment and pricing of risk, which can be used to inform decision making; a key challenge for the development community

is establishing parameters to increase resilience, and thus promote and protect development.

- To ensure that key decision makers (such as ministries of finance) see financial protection interventions as saving (as opposed to costing) money, further work needs to be done to "package" the findings that are emerging on financial protection's benefits.

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Francis Ghesquiere, head of the GFDRR, addresses participants in the closing ceremony. Photo credit: Miki Fernández.

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The Future of Risk and Risk Assessment

Disruptors:
Cutting-Edge Technologies That Are Changing the Way We Understand Risk

Amal Ali, Global Facility for Disaster Reduction and Recovery

Introduction

Disruptive innovation is arguably the sexiest concept across all industries today. The term, first coined by Harvard professor Clayton Christensen, is defined as "a process by which a product or service takes root initially in simple applications at the bottom of a market and then relentlessly moves up market, eventually displacing established competitors."[1] History affords us many examples of disruptive innovations, from the steamship, automobile, and personalized computer to mobile phones and Netflix. From these examples, one thing is clear: disruptive innovation revolutionizes the way we live, work, and communicate with others.

Background

Confronted with unpredictable weather patterns and an increase in the frequency and severity of natural hazards, disaster risk managers are looking to disruptive innovations for faster and cheaper solutions to the problems of understanding and responding to disaster risk. Emerging technologies have changed the field of disaster risk management in the last few years, and a variety of initiatives are further encouraging the development and employment of disruptive innovations in the field. The Challenge Fund of the UK Department for International Development (DFID) and Global Facility for Disaster Reduction and Recovery (GFDRR), for example, spurs innovation by funding projects to improve decision makers' access to and use of risk information.

[1] The definition is from Clayton Christensen's website at http://www.claytonchristensen.com/key-concepts/.

Case Studies

Innovative tools and technologies now available range from mobile weather stations, which provide timely information on rainfall intensity through SMS, to Think Hazard!, a simple robust tool that enables development specialists to determine the likelihood and impact of a natural hazard in their given project area.

The potential to apply innovative tools from other sectors is also promising. IBM Watson, a cognitive computing system now being used by cancer researchers, the transport sector, and the intelligence community, could have a huge impact if applied in the disaster risk management field, largely because of the richness of risk information that would be produced.

Challenges

While disruptive innovations can provide experts and decision makers alike with ample and unparalleled opportunities, there are numerous challenges to employing such technologies in disaster risk identification.

One key challenge is that the tools are often driven by supply as opposed to demand. The developers of these technologies, who often hail from developed countries, decide to build and deploy a particular tool to alleviate an observed constraint in a developing country's understanding and implementation of risk information. The developing country decision makers are often not consulted during the development stage, yet they are expected to make use of the data generated from the tools once launched. Thus neglect of the demand side can result in tools that are underutilized or that don't meet users' actual needs.

Another challenge is that adopting disruptive technologies can be difficult for decision makers accustomed to traditional established mechanisms. The tools may be perceived as too simplistic and thus unable to address critical social or environmental challenges. It is important to note that this challenge is not specific to developing countries but can be found globally in large bureaucratic institutions.

The exclusionary tendency of some disruptive innovations also poses a challenge. Tools that operate on mobile applications or pull data from social media platforms, for example, may exclude the portion of the population that lacks access to the necessary devices. Although there is a great proliferation of smart phones in developing countries, nonurban dwellers (the largest majority of any developing country population) can neither afford nor access such technologies. Given this situation, it is possible to question the validity of the data derived from such technologies, particularly when they are aggregated to a national level.

Recommendations

The challenges posed by disruptive innovations present major obstacles in the application of the tools and their outputs. But these challenges need not take away from the power of these innovations, because simple solutions are often available to meet them. For example, co-production is one way of bypassing the issue of supply-driven technologies. When tools are co-produced with decision makers, developing country governments derive a sense of ownership, and the chances of uptake are improved.

It is also possible to overcome the challenge that archaic bureaucratic systems pose for the uptake of disruptive innovations. This can be done if the producers of innovation clearly outline a robust business case for employing the product and outputs.

Finally, it is important to highlight to beneficiaries that disruptive innovations should not be viewed as a replacement of traditional mechanisms. For example, although mobile weather stations produce

One thing is clear: disruptive innovation revolutionizes the way we live, work, and communicate with others.

real-time data quickly and cheaply, they cannot be a substitute for more traditional weather stations; rather they should be viewed as complementary to existing systems.

Conclusion

The application of disruptive innovations in the disaster risk management field will inevitably continue to grow. As the nature of hazards changes, it will be incumbent upon us as practitioners to think of faster, smarter, and simpler solutions for identifying and responding to risks.

The role that challenge funds play in the development of these innovations will continue to be instrumental. With seed funding for pilot projects, disruptors can test their ideas, refine them, and scale them globally. The transformational role that challenge funds can play is evident in the M-PESA case in Kenya. M-PESA is an electronic payment that allows users to withdraw, deposit, and transfer cash through their mobile phones. The channel started as a pilot project funded by the DFID's Financial Deepening Challenge Fund. Today, more than two-thirds of Kenyans use the channel—both in rural and urban centers—and the innovation has changed the possibilities of financial inclusion programs globally. M-PESA hasn't replaced the banking system as such, but by extending basic financial services to those traditionally excluded, it has filled a gap in the market that the established financial sector could not.

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Attendees examine the Red Cross Red Crescent Climate Centre's datasculpture, "Go with the Flow," which visualizes river flow data in Togo from 2005 to 2015. Photo credit: Andrea Basso.

Rubble-strewn streets of Chautara, Sindhupalchok, Nepal.. Photo credit: © IOM 2015.

Building a Less Risky Future:
How Today's Decisions Shape Disaster Risk in the Cities of Tomorrow

Stuart Fraser, Global Facility for Disaster Reduction and Recovery
David Lallemant, Nanyang Technological University

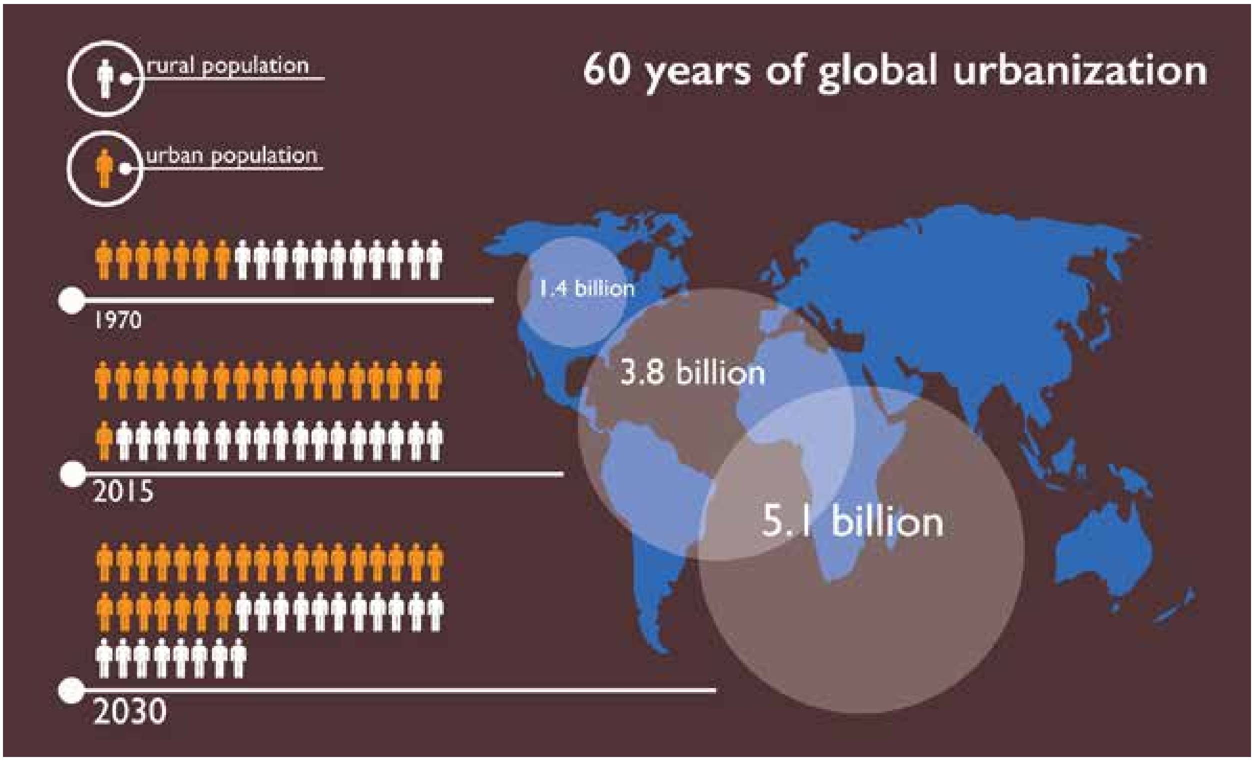
Disaster risk is constantly evolving due to changes in hazard, exposure, and vulnerability. Urbanization and population growth (figure 1) are part of this evolution—they have been key drivers of the observed increase in disaster losses over recent decades—and in 2008, urban dwellers outnumbered rural dwellers for the first time. Changes in the drivers of risk are having especially profound impacts in cities, which are often located in areas prone to flooding, earthquakes, and other hazards; nearly 1 billion people are estimated to live in areas prone to flooding, an increase of 90 percent from 1970 (Jongman, Ward, and Aerts 2012). More frequent and intense weather-related hazards due to climate change are also contributing to the evolution of disaster risk and may further aggravate the situation of the poorest urban citizens.

The future of disaster risk is being written now. In some cities, decisions on urban design and land-use planning take into account growing urban populations and evolution in cities' size and structure. In many other cities, the pace of change is too rapid for formal governance systems to keep up, and development takes place in an unregulated, ad hoc manner. In both cases, new development influences future levels of risk and resilience by creating new exposure or prompting investments with long life spans, which effectively lock in levels of disaster risk for decades to come. If decisions are taken with disaster risk and future climate conditions in mind, they may help to mitigate further increases in risk. If not, they may unintentionally increase future risk.

Urban Development and Risk

Currently, unregulated development often occurs on land parcels that may be available at a low cost precisely because they are prone to hazards. Rapid construction of buildings in such areas or on reclaimed, low-lying land immediately places more people at risk, but there is also a feedback effect in which the initial stages of development encourage further activity. In other words, increases in exposure and vulnerability can propagate in a location as the initial populations or assets attract further development and economic activity around them. By the same token, developments that locate high-density populations outside of hazard zones can alleviate risk for many years to come. It is thus possible to incorporate disaster risk reduction considerations into decision-making processes and so ensure that development helps to reduce risk over the coming years and decades. This is true not only for known risks but also for emerging risks that have been thus far neglected in many areas. For example, planning decisions and construction methods could account for hazards that are becoming more frequent or severe in our changing climate, particularly extreme heat and fire in cities.

Figure 1. The increase in global urban population between 1970 and 2030



Source: David Lallemant using data from UN World Urbanization Prospects (inspired by Population Reference Bureau infographic).

But if the importance of risk-informed decision making is clear, in practice there are multiple challenges involved in making risk-informed decisions and applying urban design principles to manage a city's risks. One major challenge is ensuring accurate assessment and continuous reevaluation of risk, which are required to enable effective risk reduction and prevent drastic increases in future losses. To be most useful for decision makers, risk assessments must demonstrate the impacts of investment on future risk and hence must be dynamic (i.e., quantify future risk) rather than static (i.e., quantify current risk based on a snapshot of data from the recent past). Only when we are able to identify and model the main drivers of risk, and demonstrate the influence of policy decisions and investments on those drivers, will we be able to improve the effectiveness of policies focused on reducing risk. In turn, dynamic risk assessment depends on having reliable sources of data that reflect the dynamic nature of population, in terms of overall growth, movement of people, and population socioeconomics. The need for data also extends to the assessment of coping capacity in order to monitor and reduce welfare losses, and ultimately reduce risk to lives and livelihoods.

As a key part of the development process, urban design should be aware of risk and make use of urban greening strategies, innovative flood defense structures, and similar approaches. But effective use of these approaches itself also relies heavily on knowing what the future riskscape might look like with and without the design in place—a fact that reemphasizes the need for robust and dynamic assessment of future risk. Designs that account for projected changes in climate and population can incorporate factors of safety into infrastructure to ensure it is robust enough to cope with future conditions, or they can use no-regret strategies (Hallegatte 2009), which provide benefits regardless of whether climate change increases the disaster risk.

Multiple emerging technologies can help us take control of a city's risk trajectory through planning and design. To match patterns of services and patterns of urbanization, planners can turn to earth observation technologies, which provide new methods for monitoring population and infrastructure growth, and which can be used to understand dynamics of risk linked with urbanization and other changes in exposure. While regional scale modeling of urban trends exists (see figure 2, for example), such analyses must be downscaled to the city and subcity scale to shed light on development patterns at the scale required by urban developers. Machine-learning approaches to population mapping, which can project future urbanization and service needs, offer tremendous potential. Since most future urban growth will occur in low-income countries where data are sparse, improved data collection—particularly focused on integration of data at high spatial and temporal resolution—is needed. In this regard, the importance of open data and open mapping to inform future planning and forecasting cannot be overstated.

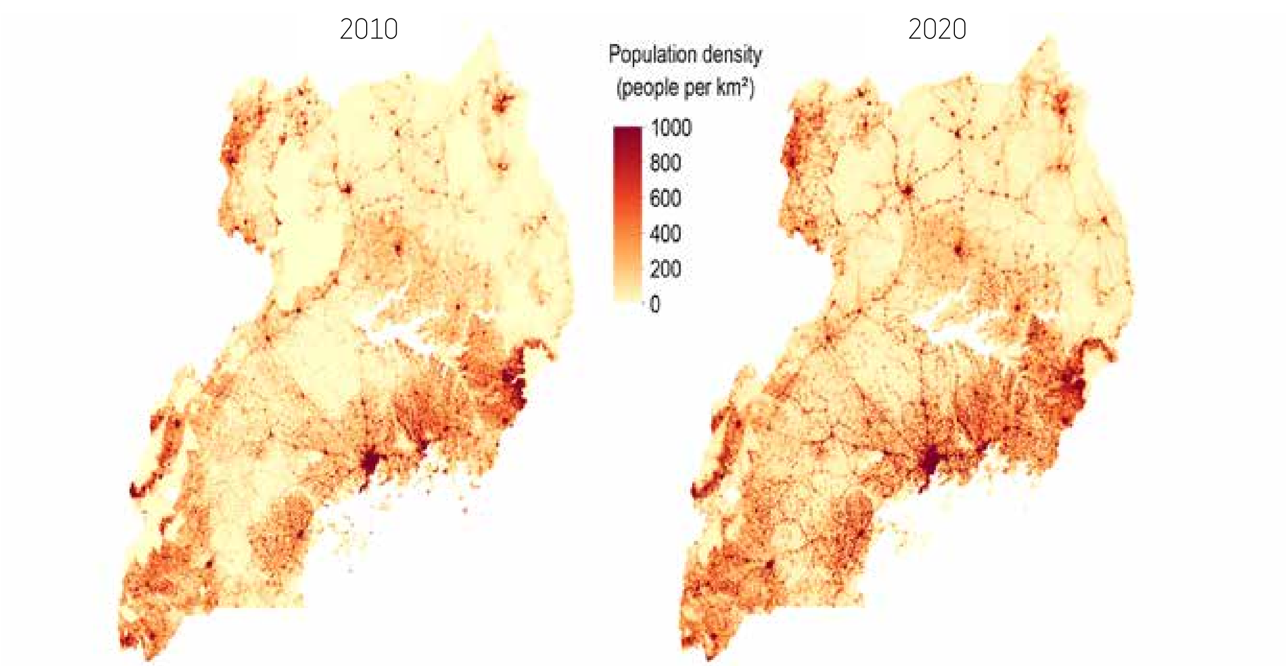
The vast majority of urban residential construction in today's growing cities occurs through the ad hoc, incremental expansion of buildings over time. New structural engineering tools are beginning to simulate these changes in buildings over time and their effect on building vulnerability (Lallemant et al. forthcoming). These tools enable us, for instance, to assess the potential influence of construction quality policy on future earthquake risk (figure 3). In parallel, time-varying hazards are increasingly being measured and monitored at a scale useful for city-level decision making (e.g., urban land subsidence, flood frequency monitoring).

Case Studies

Risk-Aware Flood Defense Design in Manhattan

To promote risk-aware design that includes great urban amenities within resilient infrastructure, it is important to link risk modelers with designers. Design systems should be adaptable so they can grow to match an inherently uncertain risk. One way of promoting adaptability is through small design interventions that facilitate learning over time through an experimental approach. Smaller projects (or projects with small, modular components) can be easier to manage in terms of governance and implementation; and if they are independent of other components in the larger system, they can be constructed to leave redundancy in the defenses (i.e., designed so that not all components fail at once).

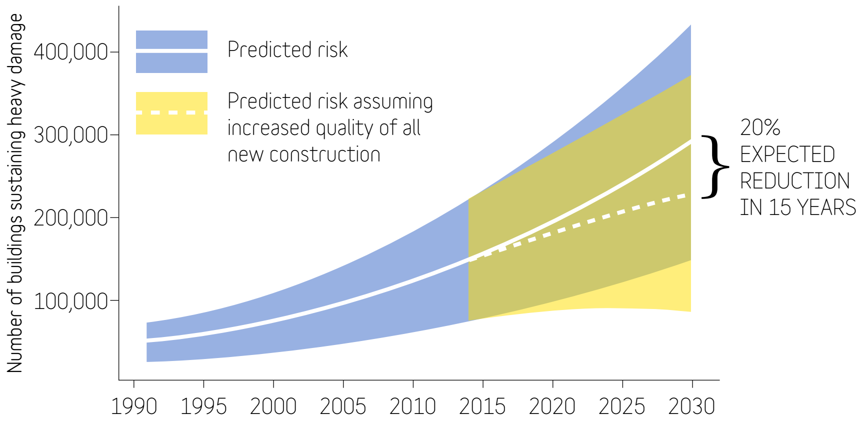
Figure 2. Simulated change in population density between 2010 and 2020 in Uganda



Source: Catherine Linard.

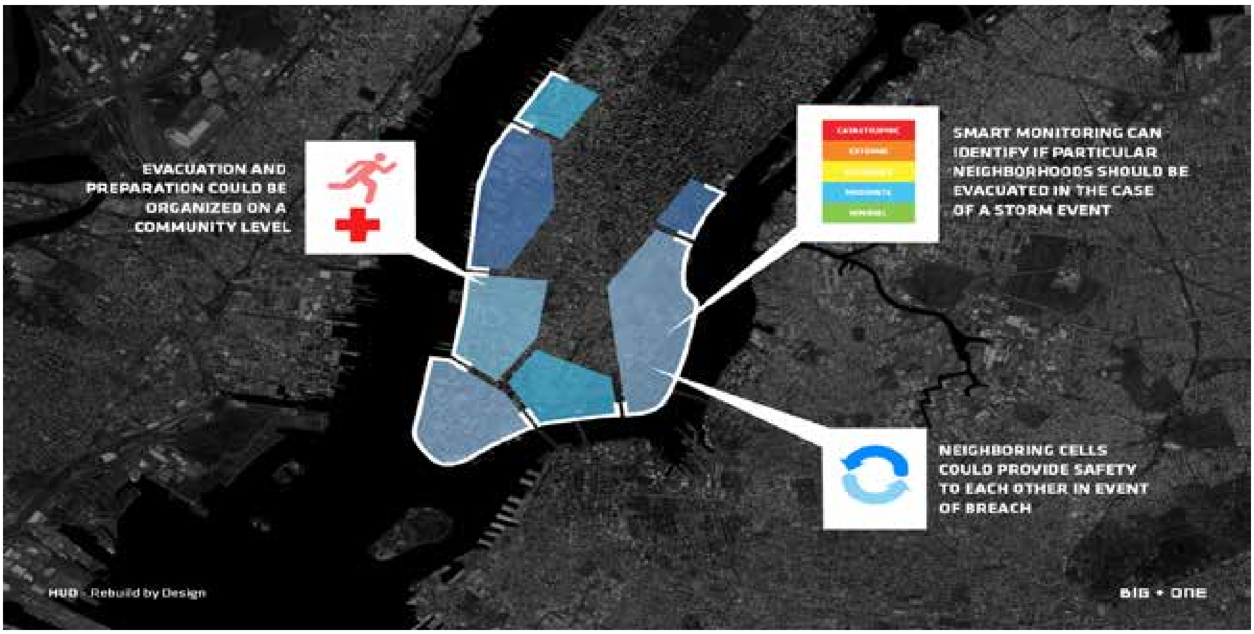
One example of this approach is the "Big U" flood defense in Manhattan, New York City, in which communities are protected by individual flood defense cells that together form a continuous flood defense. This approach also has the benefit of individual defense cells that are easily adapted, managed, and governed rather than very large infrastructure spanning multiple governance geographies (figure 4).

Figure 3. A demonstration of the potential impact of increasing construction quality on earthquake damage.



Source: David Lallemant.

Figure 4. Compartmentalized flood defense design for Manhattan, New York City. Each compartment enables flexibility because it encourages a design and risk mitigation plan relevant to that community.



Source: BIG/One Architecture.

Losses in the 2005 Mumbai Floods: Welfare and Assets

While there is much focus on *asset losses* in cities, and though the risk community is acutely aware of the impact of disasters on urban populations, risk analysis rarely accounts adequately for *welfare losses*, which can vary hugely between communities depending on their relative coping capacities. Analysis of the 2005 Mumbai floods, which differentiated between total asset losses and welfare losses for various urban communities, suggests that the urban poor are more exposed, suffer greater impacts, and have less recovery capacity than other populations (Hallegatte, Bangalore, and Vogt-Schilb 2016). Poor people were disproportionately affected by the floods (39 percent versus 18 percent of the nonpoor population) and lost relatively more (13 percent of income versus 9 percent of income). Furthermore, overall welfare losses, estimated at Rs 60 billion ($890 million), were much higher than asset losses, estimated at Rs 35 billion (over $500 million).

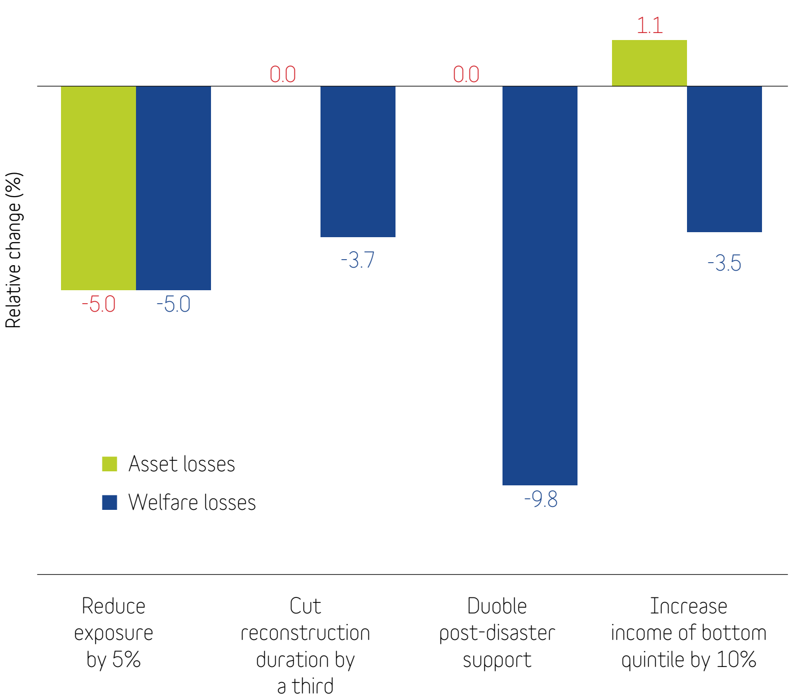
A socioeconomic resilience tool developed by the World Bank (Hallegatte, Bangalore, and Vogt-Schilb 2016), which includes modeled coping capacity, can be used as a policy tool to estimate the impact of policies on welfare losses. The tool shows that disaster-based social protection can decrease welfare losses, even in cases where asset losses increase (figure 5). A key challenge to improving consideration of welfare losses is data availability at the detailed level—for example, data on which groups of people live in which houses. Such high-resolution exposure data are not ordinarily captured in typical risk models, particularly those covering a regional or national domain. Asset inventories exist to assess impacts on poor people versus wealthy people, but better communication between analysts and local authorities or communities would help to show the value of detailed data and enable sharing to improve assessment.

Conclusion

This discussion highlights just a few of the issues and challenges involved in better measuring and predicting future risk. Collectively, the approaches can guide risk-sensitive urban policy and planning by demonstrating potential trajectories of cities' risk and the impact of policies made today on these trajectories.

An immediate goal is to incentivize risk-based decision making by sharing risk management messages and success stories with decision makers. This can be done only with increasingly effective communication, via multiple avenues that tell a story of changing risk—and make clear what could happen if a certain decision is or is not made. Underlying this approach is a need for some quantification of future risk to assess the range of options objectively: which options increase risk, which options reduce risk, and by how much relative to their cost?

Figure 5. Impact of several strategies to reduce welfare losses in Mumbai.



Source: Hallegatte, Bangalore, and Vogt-Schilb 2016.

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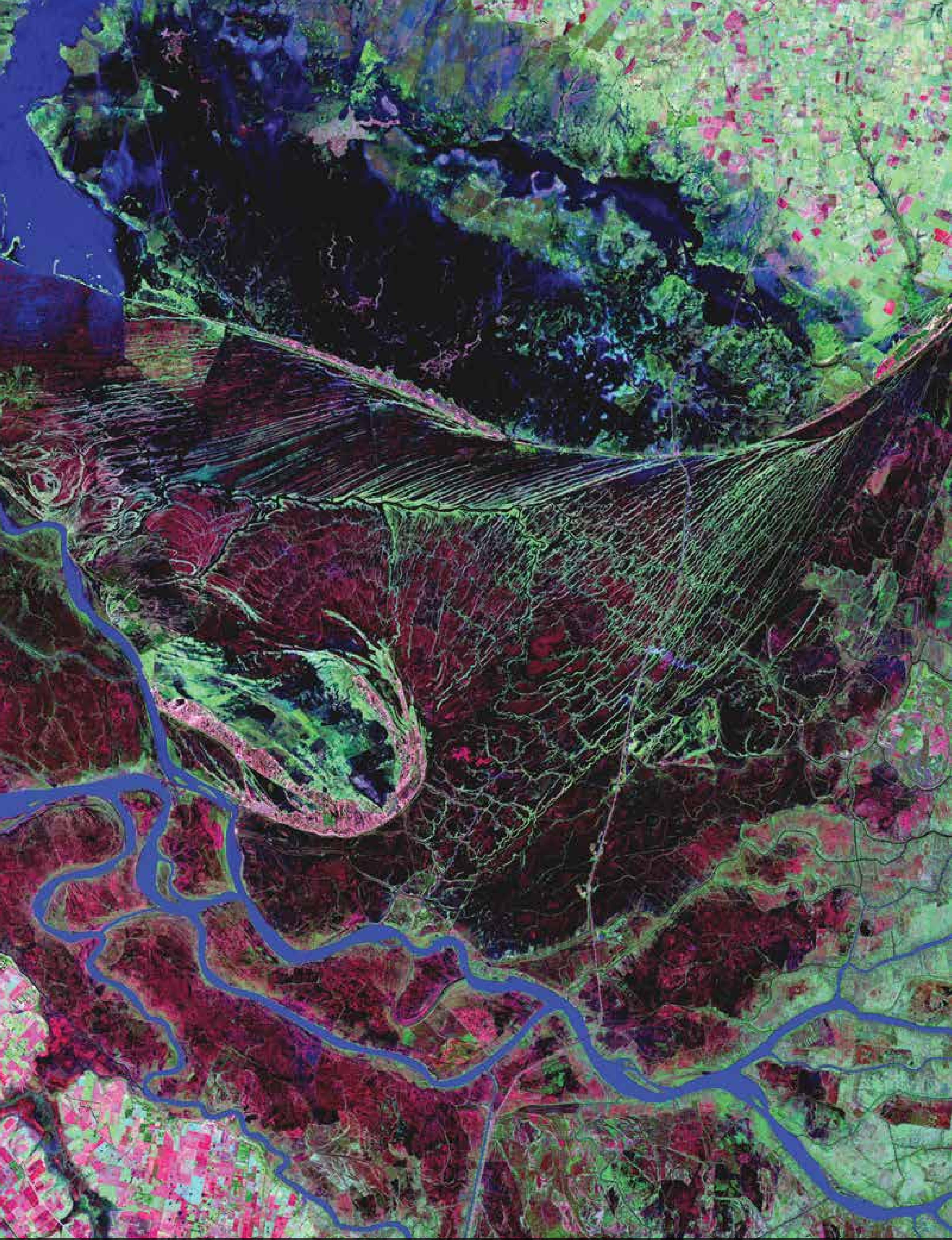

The Parana River delta is a huge forested marshland about 20 miles northeast of Buenos Aires, Argentina. This image highlights the striking contrast between dense forest and wetland marshes, and the deep blue ribbon of the Parana River. Photo credit: USGS EROS Data Center.

The Domino Effect: The Future of Quantifying Compounding Events in Deltas

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Toward Multihazard Interacting Risk Assessment Methods

Priority 1 of the Sendai Framework for Disaster Risk Reduction 2015–2030 (Understanding Disaster Risk) advocates moving research and development in disaster risk management toward more comprehensive multihazard approaches (UNISDR 2015). Currently, however, there exist limited guidelines or methods in science for assessing natural hazard risks while also considering hazards' complex dynamics and interactions. Interactions between different natural hazards (e.g., floods, volcanos, earthquakes) can exacerbate their associated risks by influencing one or more of the three factors of the risk framework: hazard, exposure, and vulnerability. For example, one natural hazard could increase the likelihood of another kind, could leave society more exposed to the next, or could leave the exposed society more vulnerable to impacts from the next.

Case Studies

Case studies on interactions between natural hazards in the Philippines, the Netherlands, and the United States are presented below. They raise significant questions about the impacts of compounding events on society, the way in which an "event" should be presented to stakeholders, and the importance of collecting more evidence and data that can relate impacts to a multihazard cascade.

Figure 1. Ruins of homes destroyed by the lahars and floods on Mount Mayon in 2012.

Source: © Melanie Duncan. Reproduced with permission from Melanie Duncan; further permission required for reuse.

Philippines: Cascading Hazards

The Philippines is exposed to multiple natural hazards. In the area surrounding the active volcano Mount Mayon (figure 1), the impact of typhoons is aggravated by increases in the probability of lahars (volcanic mud flows). In 2006, the area was hit by typhoons in September and November. The second and more intense typhoon struck while communities were still recovering from—and experiencing increased vulnerability as a result of—the first typhoon. The second typhoon triggered intense lahars that killed over 1,000 people living on the slopes and at the foot of the volcano. These consecutive events showed that communities' vulnerability is dynamic and dependent on earlier hazard events.

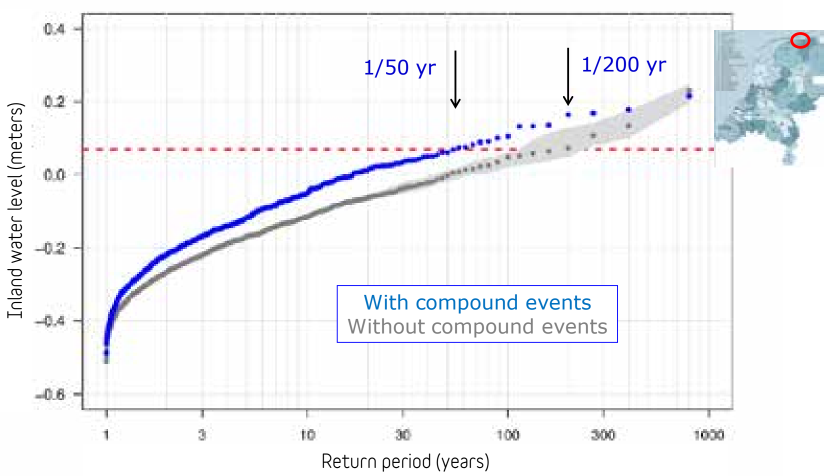
Netherlands: Storm Surge and Rainfall

When storm surge and heavy rainfall occur jointly in a coastal area of the Netherlands, the resulting floods can have a particularly severe impact on society. In 2011, the two hazards—a heavy surge event and a concomitant heavy rainfall—coincided in the northern Netherlands. Individually, the surge and rainfall were not extreme, but their compounding impacts resulted in a serious and long-lasting impediment to free drainage, which almost led to severe flooding in the area, which is well known for its high flood protection standards. Figure 2 shows how the probability distribution of extreme water levels in Lauwersmeer, a lake in the northern Netherlands, changes when compound surge and rainfall events are accounted for (Van den Hurk et al. 2015).

United States: Tropical Cyclones and Rainfall

The Houston, Texas, region of the United States is exposed to tropical cyclones and heavy rainfall events. A study of this region shows that the U.S. Federal Emergency Management Agency's (FEMA's) 1 percent

Figure 2. Return level of inland water level at Lauwersmeer without consideration of compound flooding (grey) and with (blue). The red dashed line indicates the highest warning level for this station.



Source: Van den Hurk et al. 2015.

floodplain, which is used as a primary flood risk marker, does not incorporate the risk from compound flood processes. This boundary, representing the extent of *either* riverine *or* storm surge flooding, drives policy decisions regarding flood mitigation, insurance purchases, local planning, and building construction. But while the flood hazard from both riverine and surge hazards are mapped individually, they are not mapped jointly, and this failure may be contributing to much higher numbers of insurance claims than anticipated. The empirical evidence indicates that in some coastal watersheds, more than 50 percent of flood claims occur outside of the mapped floodplain boundaries. Research suggests that by neglecting to consider the interaction between storm surge and rainfall-runoff in coastal watersheds, current policy is allowing for—and potentially driving—development in already flood-prone areas, hence making communities more susceptible to cascading hazards.

Stakeholder-Centered Approach

In order to solve the puzzle of compounding events, it is essential to start the conversation at the impact side: what causes societal disruption, damage, and loss of life? This approach also helps to circumvent the problem of considering different natural hazards together when they are measured using different metrics or at different scales. By focusing on the impact, different natural hazards and their combined effects are more readily comparable. For example, because storm surges are often modeled at the regional scale, while pluvial floods are modeled at the local scale, it is difficult to combine these two hazards into a single evaluation. But by focusing on the impact, the two hazards do not need to be communicated separately, and instead they can be evaluated by their combined effect in one and the same unit.

All three case studies show the importance of starting with the particular impacts to particular stakeholders in order to better understand compounding events. This focus showed that in the Philippines, compounding events play a role in creating dynamic vulnerability, that in the Netherlands, they can lead to unanticipated extreme water levels, and that in the Houston, Texas, region, they may call into

Flooding in Raymondville, another area of Texas prone to floods, during Hurricane Dolly (July 2008). The FEMA floodplain demarcates where development should occur, how high to build structures, and whether to buy flood insurance.
Source: Jacinta Quesada/FEMA.

question the accuracy of current flood mapping approaches.

This focus on impacts on stakeholders also suggests the importance of local knowledge for hazard assessment. Early participation by local stakeholders makes it possible to identify which real-world events (e.g., floods, fires, failed infrastructure) cause societal disruption. Communities exposed to multiple natural hazards may already be dealing with interacting hazards, and therefore their insight and experience can help inform future research. As the magnitudes by which we measure impacts can be equal across all disciplines, such a bottom-up approach to assessing multihazard risk can make future interdisciplinary risk modeling successful. We advocate that the research community take this stakeholder-centered approach to defining probabilistic event sets based on their impacts. As it becomes increasingly apparent that the most devastating "events" are a function of multiple hazards occurring in sequence (by triggering or aggravation), studying cascading natural hazards will become an interdisciplinary field.

One challenge presented by this approach is communicating multihazard risk to end-users. We believe that focusing on direct real-world impacts (e.g., loss of life, failed infrastructure, impeded economy) as a result of multihazards is key to communicating multihazard risk to the end-user. As already noted, focusing on the end impact also allows scientists to overcome difficulties in measuring hazards across different scales and disciplines.

Conclusions and Looking Forward

Scientists and consultants are accustomed to identifying risks in a single causal way. We tend to start with a typical model cascade and evaluate the direct impacts of a single hazard. Hydrologists, for example, may start with meteorological data, feeding into hydrological models, hydraulic models, and consequently impact models. Significant advances have been made toward developing more probabilistic approaches to hazard assessment, but further advances are necessary if we wish to address the interactions between, and compounding effects of, multiple natural hazards. The starting point should be a dialogue between local stakeholders and experts about the impacts that lead to societal disruption. These local impacts could be very different for different stakeholders, and are highly dependent on the local context and system properties. This dialogue should reveal which real-world events have the strongest societal impacts, and which models and data are required to investigate these. A check on the robustness of a multihazard risk assessment should be applied by testing the sensitivity of impacts to smaller or larger perturbations to the key drivers or variables in the system. Development of more integrated risk models to assess combined impacts is required.

Information about natural hazard interactions and the attribution of societal impacts to multiple hazards is still limited. This is first of all due to the fact that databases of natural hazard events generally attribute damages to the primary hazard, while secondary hazards may in fact cause equally large impacts. For example, the major earthquake in Christchurch, New Zealand, triggered large-scale liquefaction, and this liquefaction caused about 50 percent of the total damage—but most databases record these losses as due to the primary earthquake event. To support the assessment of probabilities, we should begin by describing disasters in terms of their impacts and associate these with the full set of natural hazards that occurred. Guidelines and principles on how to do this need to be further developed in the years to come.

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The starting point should be a dialogue between local stakeholders and experts about the impacts that lead to societal disruption.

Understanding Risk Is Essential for the Implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030: Targeting the Future with Science and Technology

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Introduction and Background

The Sendai Framework for Disaster Risk Reduction 2015–2030 was adopted by 187 United Nations (UN) member states in March 2015 and was endorsed by the UN General Assembly in June 2015. The main outcome of the Sendai Framework is "the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries" (UNISDR 2015).

The discussion below describes some of the work being done under the Sendai Framework. It also highlights the challenges and opportunities presented by implementation of the framework, based in part on the outcome of the UNISDR (United Nations Office for Disaster Risk Reduction) Science and Technology Conference on the Implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030,[1] held in January 2016, and on the launch of the UNISDR Science and Technology Partnership and the Science and Technology Road Map to 2030. The UNISDR Science and Technology partnership will focus on the need for local, national, regional, and international collaboration and on the four priorities identified in the framework:

- Priority 1: Understanding disaster risk
- Priority 2: Strengthening disaster risk governance to manage disaster risk
- Priority 3: Investing in disaster risk reduction for resilience
- Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction (UNISDR 2015).

Case Studies

National: How Uganda Has Domesticated the Sendai Framework

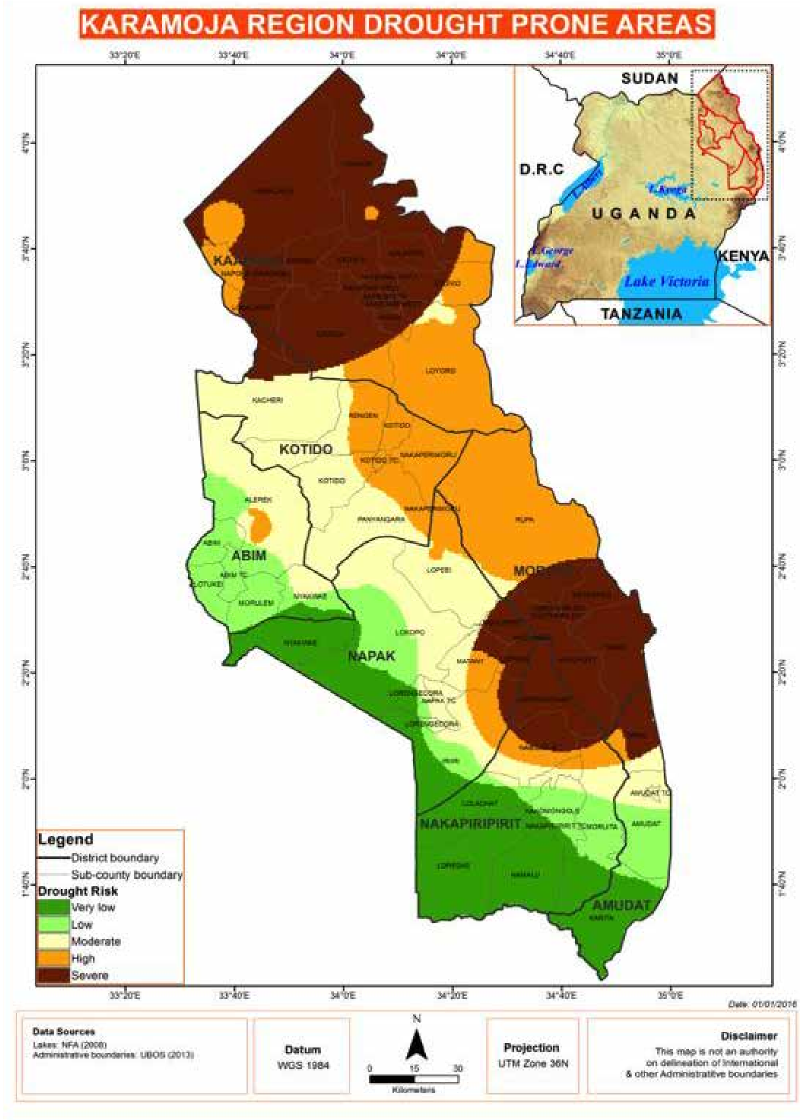
Since the Hyogo Framework for Action 2005–2015 was first endorsed, Uganda's National

[1] Information about the conference is available at http://www.unisdr.org/partners/academia-research/conference/2016/.

Platform for Disaster Risk Reduction has been fine-tuned and made more robust, in part by increasing the diversity of stakeholders to include decision makers, professionals, scientists, and members of the private sector. More generally, Uganda has acted to improve disaster preparedness and mitigate disaster risk in a number of ways:

- The National Policy for Disaster Preparedness and Management has been undergoing continuous review since 2011 to ensure alignment to the Sendai Framework, and it will soon be developed into an Act of Parliament.
- With the support of the United Nations Development Programme, Uganda has mapped hazard, risk, and vulnerability within the country. Drought, one of the most common hazards in Uganda (see figure 1), has been a particular focus of these efforts. Drought risk for the Karamoja subregion has been mapped according to severity, allowing interventions and resources to be directed toward the most vulnerable. Cash interventions for vulnerable individuals have been designed by the World Bank.
- In 2014, Uganda launched the National Emergency Coordination and Operations Centre, which aims to provide early warning information, carry out modeling and forecasting, and coordinate emergency response. The Department of Meteorology has been reconstituted as the Uganda National Meteorological Authority, with new investments in scientists, procurement, and technology, and is becoming a focal institution for the Intergovernmental Panel on Climate Change.
- The Ministry of Health has improved its capacity and manpower to monitor and respond to infectious disease outbreaks. The minister anticipates the establishment of a new Parliament for Disaster Risk Reduction, which would require the input of scientists and diverse experts.

Figure 1. Map showing drought vulnerability of populations in different parts of Uganda



Source: © Department of Relief, Disaster Preparedness and Management, Office of the Prime Minister, Uganda. Used with permission; further permission required for reuse.

Challenges in addressing disaster risk still persist, such as inadequate dissemination of weather forecast information to stakeholders, decentralization of disaster preparedness and response to local authorities, and lack of investment in science and technology to deliver risk assessments to local end-users. But there has also been notable progress, seen in the development of contingency funding to those most at risk, and in the establishment of partnerships with the wider global scientific community to ensure science is useful, usable, and used.

Regional: Disaster Risk Management Knowledge Centre

The Disaster Risk Management Knowledge Centre (DRMKC) is a European Commission initiative to improve the science and policy interface in the area of disaster risk reduction. Launched in September 2015, the DRMKC is founded on three pillars—partnership, knowledge, and innovation—and works under six expected outcomes (shown in figure 2), mainly to improve communication between policy makers and scientists and offer European Union countries scientific and technical advice.

The DRMKC makes all its data and publications public, and invites all interested parties to submit events, research project results, and success case studies to build up its library. More details can be found at http://drmkc.jrc.ec.europa.eu/.

Figure 2. Expected outcomes of the DRMKC

Source: Joint Research Centre of the European Commission.

International: The Role for Risk Modeling

The important role of risk modeling, which is outlined by Priority 1 under the Sendai Framework, is evident in the work of Risk Management Solutions (RMS).[2] RMS uses a catastrophe modeling framework to perform estimates on losses due to a catastrophic event. The RMS modeling framework includes five modules: exposure, event, hazard, vulnerability, and financial analysis. Currently, the framework is mostly used in the insurance industry, but RMS anticipates an expansion in which high- and middle-income governments use it to better plan resources and infrastructure for imminent hazards. In the further future, RMS hopes to engage governments to develop their own models that best suit their individual needs. However, such expansions would require the improvement of local capacity and development of national and regional risk data and risk platforms.

Challenges

There are a number of challenges that face countries as they seek to implement the Sendai Framework:

- One of the biggest challenges is increasing policy makers' awareness of scientific, technological, and industrial knowledge and skills. Partnerships between policy makers and the scientific community should provide opportunities for increasing access to information.
- While the Hyogo Framework for Action focused on processes, the constructed indicators did not lead to the achievement of

2 For more information, see the RMS website at http://www.rms.com/.

goals. To ensure that the goals of the Sendai Framework are met, research must be targeted and scientists must work with policy makers toward the same goals. Instead of focusing on hazards and emergency response as in the past, the scientific community should adopt an integrated approach and undertake all-hazards research. This change could lead to integrated policy making focused on risk; Mozambique, for example, instituted a dramatic change in approach in moving from the Hyogo Framework for Action to the Sendai Framework.

- Standardizing disaster data around the world, which would considerably benefit implementation of the Sendai Framework, remains a challenge. Projects are under way to address this challenge, including the Integrated Research on Disaster Risk project, which is sponsored by the International Council for Science, the International Social Science Council, and the United Nations International Strategy for Disaster Reduction. This project aims to provide a forum for information dissemination, networking, and collaboration for the growing number of stakeholders from different disciplines and sectors who study issues related to the collection, storage, and dissemination of disaster loss data. With the help of organizations such as the DRMKC, some of the project's work can be shared more widely.
- Hazard-prone and vulnerable island states face particular challenges in reducing disaster risk. They may be omitted from global tools, and because of financial constraints have difficulty collaborating with like countries.

Although each country may be different, the global community must work together; scientists' research and outputs can help to support this approach.

Recommendations

Implementation of the Sendai Framework can be furthered by the following:

- *National leadership and regional collaboration*. One of the keys to success in the swift implementation of the Sendai Framework is identifying national leaders who will involve a wide range of stakeholders in planning actions. These leaders should partake in regional and global partnerships to address cross-border issues, establish global standards, exchange best practices, and benefit from pooled resources.
- *Integrated research*. It is important to promote and improve dialogue and cooperation among scientific and technological communities, other relevant stakeholders, and policy makers in order to facilitate a science-policy interface for effective decision making in disaster risk management.
- *Engaging industry*. Industry has solved many of the challenges faced today by the public sector, and it can provide a valuable source of expertise and knowledge for successfully implementing the Sendai Framework. The insurance industry, for example, operates on the basis of its ability to measure and manage risk, and similar methods could be applied more broadly for disaster risk reduction.
- *Engaging the young*. Children are the owners of the future and should understand a little about disaster risk reduction and management before they assume positions of responsibility. To ensure they have the necessary knowledge, interactive workshops about disaster risk reduction can be incorporated into the school curriculum. Young people should also be educated about local hazards in order to build local capacity and enable them to work in an all-hazards approach.

Conclusions

As countries seek to implement the Sendai Framework, the following should be kept in mind:

- Although each country may be

different, the global community must work together; scientists' research and outputs can help to support this approach.

- Establishment of knowledge centers should facilitate the periodic review of what knowledge is available and what knowledge gaps persist. Centers should also support open access, multihazard data platforms, and standardized approaches and tools for mapping and using data and scenarios.
- To improve collaboration, an all-hazard approach—and the rejection of the term "natural disasters"—could be useful.

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See you in 2018!

What is Understanding Risk?

Understanding Risk (UR) is a global community of over 6,500 experts and practitioners in the field of disaster risk assessment and risk communication. This vibrant community—a diverse group of people from the private, public, nonprofit, technology, nongovernmental, and financial sectors—meets at the UR Forum every two years. Each iteration of the UR Forum has produced new ideas and partnerships that have improved risk assessments and helped to integrate them into policy making and development planning. This publication captures the experiences, lessons, and best practices in the field discussed at the fourth UR Forum, held in Venice, Italy, from May 16 to May 20, 2016.

"The key to good disaster and climate risk management is a better understanding of the risks we need to manage. It was fantastic to see a global cross-section of the risk community come together in Venice to advance the innovations and best practices that will facilitate informed decision making and help increase countries' resilience now and into the future. UR2016 was an inspiring and engaging event that will be remembered for years to come."

—Laura Tuck, Vice President for Sustainable Development, World Bank Group

"It was an honor to welcome the fourth Understanding Risk global forum to Venice, Italy. We saw a dynamic group of individuals and organizations that are key to advancing resilience in cities and countries around the world. Congratulations on the success of this year's forum!"

—Letizia Fischioni, Legal Advisor, Italian Agency for Development Cooperation

"The opportunity that the Understanding Risk Forum provides is instrumental in forming new contacts outside my field. These contacts will help us serve our clients and better manage their disaster and climate risk. It was a delight to be a part of an exciting event like UR2016."

—Esther Baur, Director, Global Partnerships, Swiss Re

"Through the Understanding Risk community, I have met over a dozen people and organizations that I later collaborated with. We have bid on projects together, developed new ideas for the evolution of risk management tools, created geographic partnerships, and replicated and scaled projects. UR events are an efficient means to meet with a broad network of disaster risk management users and practitioners."

—Andrew Eddy, President and Chief Executive Officer, Athena Global

"The participants in the conference came from a fascinating variety of backgrounds in science, policy, the insurance industry, emerging economies, and many others. Discussion of the contribution of space observation to understanding risk had a receptive and lively audience—the connections and contacts I made have already been followed up in my work and will contribute to greater innovation in the future. Thank you for the opportunity to be a part!"

—Stephen Briggs, Senior Adviser for Earth Observation, European Space Agency; and Chairman, Global Climate Observing System

"Understanding Risk has helped expand the space of possibility in how we design and facilitate sessions and context for meetings. I would recommend this conference to others, as UR cares for the importance of informal interactions—fun, cool, vibrant events enable new friendships and trusted relationships."

—Pablo Suarez, Associate Director for Research and Innovation, Red Cross Red Crescent Climate Centre

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