UNDERSTANDING RISK

Innovation in Disaster Risk Assessment

Proceedings from the 2010 UR Forum

Published in Washington DC November, 2010
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Manufactured in the United States of America
First printing November 2010

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Thank you:
To the UR Community

With five hundred attendees representing over one hundred countries, the Understanding Risk (UR) Forum was a truly global event that brought together disaster risk management experts and practitioners from around the world. This community, however, extends beyond the forum attendees to the eighteen hundred on-line participants. It was in this collaborative and participatory spirit that the UR Community was born and we would like to thank every one of you for your contribution and dedication to sharing your knowledge and expertise in innovative disaster risk assessment approaches.

There are an overwhelming number of people that helped build the UR community. We cannot mention them all, but a few stand out. In particular, we would like to give a special thanks to the Session Leads who provided so much time and effort in organizing their sessions, moderating the on-line dialogue, presenting in the Ignite, and writing the summaries you will read in this publication. Thank you to: Diego Arias, Lauren Augustine, Hannah Brenkert-Smith, Omar D. Cardona, Rowan Douglas, Ron Eguchi, Daniele Ehrlich, Sushil Gupta, Chris Holmes, Daniel Kull, Patrick Meier, Stuart Miller, Sergio Mora, Praveen Pardeshi, Edward Pickle, Rui Pinho, Mark Rasmuson, Paolo Reggiani, Julio Serje, Kenneth L. Verosub, Olga Wilhelmi, and Mary Lou Zoback.

We would like to extend our gratitude to all our UR partners: UR was sponsored by the Global Facility for Disaster Reduction and Recovery (GFDRR), infoDev and the Knowledge Strategy Group (KSG), in partnership with the Global Earthquake Model (GEM) and the United Nations International Strategy for Disaster Reduction (UN ISDR). Collaborative UR partners include: the Academy of Educational Development (AED), AIR – Worldwide, Center for International Earth Science Information Network (CIESIN)— Earth Institute Columbia University, Deltares/Delft Hydraulics, Disaster Resistant Business (DRB) Toolkit, the European Commission Joint Research Center (JRC), Evaluación de Riesgos Naturales (ERN), FortiusOne, the Haiti Poster Project, ImageCat, Intermap Technologies Risk Management Applications, the International Federation of Red Cross and Red Crescent Societies (IFRC), Leica Geosystems Geospatial Solutions, the National Academies, the National Center for Atmospheric Research (NCAR), OpenGeo, the United Nations Institute for Training and Research (UNITAR), Operational Satellite Applications Program (UNOSAT), Ushahidi, V1 Magazine, and the Willis Research Network. Additional partners included Google, Microsoft, NASA, the U.S. State Department and Yahoo! for the Random Hacks of Kindness event and the Crisis Commons for the DC Crisis Camp.

A big thank you to our keynote speakers: Aneesh Chopra, Rowan Douglas, Shelley B Leibowitz, Ed Parsons, and Margareta Wahlstrom. To the entire World Bank Understanding Risk Team: Aires Conceicao, Ana Daza, Ana Maria Torres, Armando Guzman, Bradley Lyon, Emma Phillips, Fernando Ramirez Cortes, Francis Ghesquiere, Galen Evans, Joaquin Toro, Laura Dorling, Luis Corrales, Niels Holm-Nielsen, Noosha Tayebi, Oscar Apodaca, Oscar Ishizawa, Ross Gartley, Stuart Gill, Tiguist Fisseha, Trish Barrett, Ulrich Myboto, Violeta Wagner, and Zuzana Tomkova—thank you for your time, energy, and creativity in making this conference a reality. We would also like to thank the World Bank's General Services Department for all their hard work and SecondMuse for helping us put together the community site.

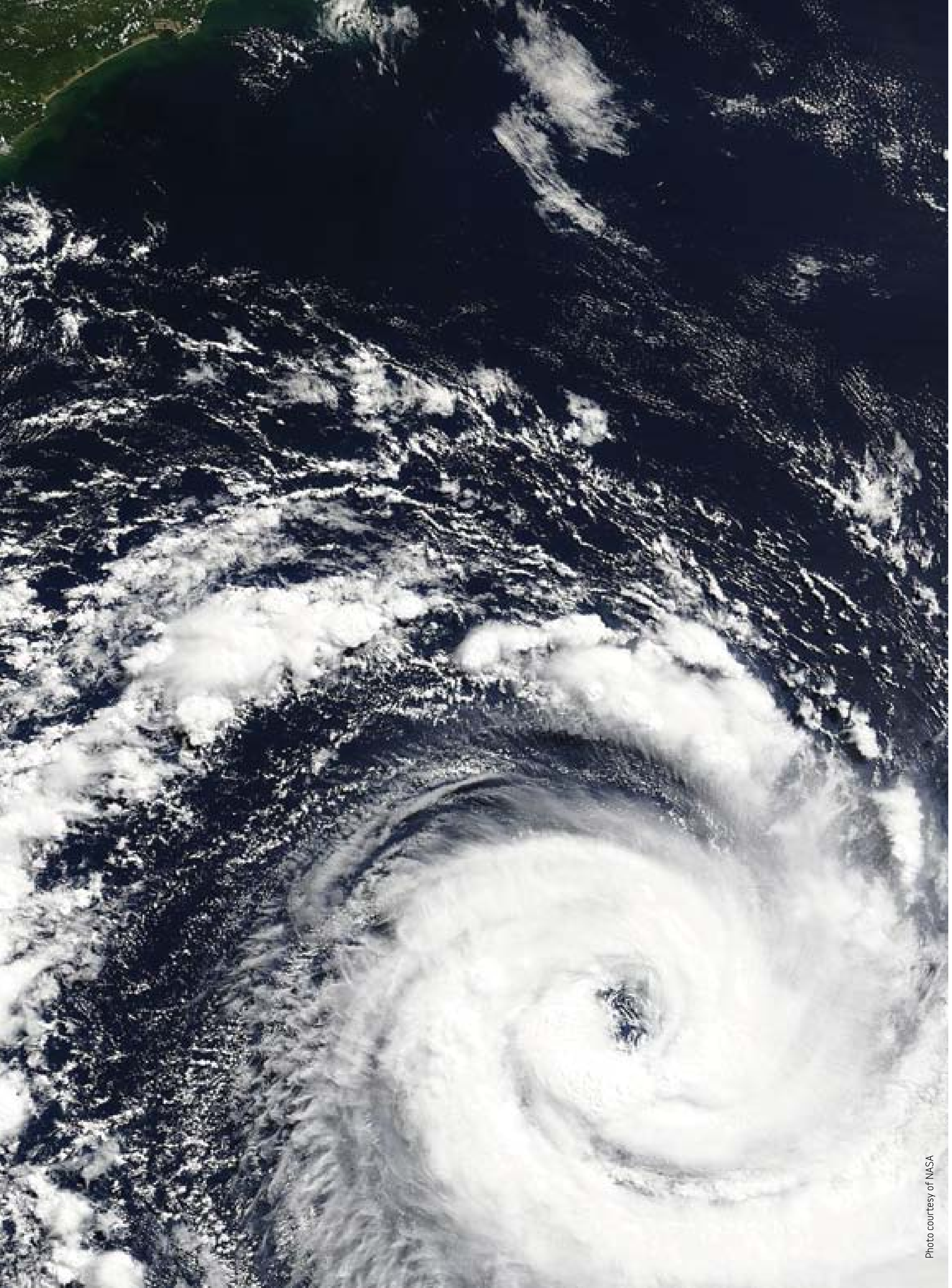

Photo courtesy of NASA

Disaster Risk:
Confronting the Inevitable

Less than two months after it convened in Washington, DC, in June 2010, the *Understanding Risk Forum* took on fresh and grim relevance when monsoon floods swept through Pakistan, killing nearly 1,500 people and leaving 20 million homeless.

The *Forum* brought together 500 disaster risk experts and practitioners, representing government agencies, research institutions, multilateral organizations, private sector firms, nongovernmental organizations (NGOs) and community-based organizations involved in disaster risk assessment—all of whom are searching for better ways to confront and reduce risks of future—and increasingly likely—calamities like the one that struck Pakistan.

Speaker after *Forum* speaker emphasized the message summed up in the eerily prescient words of closing keynoter Margareta Wahlström, UN Assistant Secretary-General for Disaster Risk Reduction:

"Many countries today can pretty well pinpoint the location [of the next natural disaster]. It's going to happen, if not this year, next year."

But recognizing the inevitability of disaster—driven to a great extent by incautious development in environmentally sensitive areas and a changing climate—is only a first step, as Wahlström and other speakers said. Beyond responding to disasters, the bigger, more difficult step is developing best practices for taking forehanded action to assess and minimize their impact.

Rowan Douglas, Chairman of Willis Research Network, a global risk management and insurance intermediary based in London, said in wrapping up the *Forum:*

"The main questions posted were: 'What is risk? Can we measure it? If we understand it, can we manage it better?' The answer to all these questions is an absolutely emphatic yes."

Douglas' unhesitant yes was backed up by three days of presentations where risk experts and practitioners from around the world detailed the fast-paced innovation in risk assessment. From first-hand experience, they impressively documented what can be done to better understand the potential impact of the next monsoon floods in South Asia, earthquakes in the Caribbean and Latin America, tsunamis in East Asia, and droughts in Sub-Saharan Africa. Technology—some of it now as ubiquitous as the mobile phone—is leading much of the innovation. Speakers at nearly every presentation stressed that the best strategies and practices won't pay off unless they engage all the stakeholders, beginning with vulnerable local communities, where the risks lie waiting to become disasters.

On the following pages are summaries of presentations by leaders of *Forum* sessions. The presentations and video recordings of the sessions can be found on the UR website at: www.understandrisk.org.

Francis Ghesquiere
Understanding Risk Team Leader

The Challenge: Finding Innovative, Practical Solutions

What is risk? Can we measure it? If We understand it, can we manage it better? *The Understanding Risk (UR): Innovation in Disaster Risk Assessment* conference addressed these important questions. The event explored best practices in a variety of topics ranging from open source risk modeling to community-based risk assessments. New approaches in risk assessment were showcased, focusing on technological developments and the benefits of inclusive partnerships.

The UR conference was attended by officials from government agencies, research institutions, multilateral organizations, private sector firms, nongovernmental organizations (NGOs) and community-based organizations involved in disaster risk assessment. Prior to the conference a series of on-line discussions on the session topics were led by experts in the field at the UR community site: www.understandrisk.org. The UR community site was built as a platform for experts and practitioners in disaster risk management to exchange ideas, share information, and discuss innovative risk assessment practices.

UR was organized in conjunction with the Outreach Meeting of the Global Earthquake Model (GEM) initiative. Other side events included a DC Crisis Camp organized by the Crisis Commons (www.crisiscommons.org) and a global Random Hacks of Kindness hackathon (www.RHoK.org)—a joint partnership with Google, Microsoft, Yahoo!, NASA, and the World Bank.

Haiti January 12 and Beyond

The earthquake and earthquake hazards

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On January 12, 2010, a 7.0-magnitude earthquake took place in Haiti (maximum intensity of X+ on the Modified Mercalli Scale), claiming approximately 230,000 lives and injuring 100,000 people. Almost 600,000 people were left homeless and nearly 300,000 were displaced. These figures are in addition to another sizeable portion of the population in a similar situation as a result of the combined effects of poverty exacerbated by previous disasters and political upheaval, which have plagued Haiti for many years. The earthquake also caused landslides and liquefaction of soft soils over large expanses of the country, and segments of the coast were subject to subsidence and cortical uplift as well as a minor tsunami. This situation has resulted in profound psychosocial trauma in addition to damages and economic losses totaling almost US$ 8 billion, all of which represents a setback to the country's recovery efforts and development process in the wake of the hydro-meteorological and political problems in which Haiti has been mired in recent decades. It is not the first time—nor will be the last—that a powerful earthquake hits the island of Hispaniola and Haiti in particular.

This earthquake was the materialization of a natural hazard, but the true catastrophe was largely man-made: a collusion of moderate to strong shaking with a dense population living and working in largely substandard construction.

While the occurrence of the earthquake was anticipated and public officials had been notified of that fact, its precise timing was unknown. Like the vast majority of damaging quakes, it occurred without warning. Geologists working on Hispaniola had identified both the Enriquillo-Plantain Garden fault in the south and the Septentrional fault in the north as major ~E-W plate boundary fault zones transecting Hispaniola and established a potential for M7+ earthquakes on both based on past offsets of stream features (Mann & Prentice et al., in preparation). The January 12 earthquake ruptured ~50 km long segment of a north-dipping fault within the Enriquillo-Plantain Garden system, with significant components of both vertical and horizontal slip. The segment that slipped was located west of Port au Prince. Secondary hazards related to the earthquake include: a small tsunami (that killed 4 people near Léogâne), areas of both coastal uplift and subsidence, and a wide area affected by slope failure (landslides, rock-falls), and liquefaction.

The last major earthquakes along this stretch of the Enriquillo-Plantain Garden fault zone occurred in 1751 and 1770. Since that time the fault zone has remained largely "locked", while continuous plate tectonic motion at depth reloads the fault and causes slow deformation on the earth's surface, just like a thick rubber sheet being sheared. Geophysicists analyzed Global Positioning System (GPS) signals captured by instrumentation at precisely fixed benchmarks on the ground and determined a loading rate of 7-10 mm/yr for the Enriquillo-Plantain Garden fault. A scientific paper published in 2008 used 240 years since the last major earthquake to obtain 1.7 to 2.4 m of potential slip and concluded that the Enriquillo fault "was currently capable of a Mw7.2 earthquake if the entire elastic strain accumulated since the last earthquake was released in a single event today" (Manaker et al., 2008).

This earthquake was the materialization of a natural hazard, but the true catastrophe was largely man-made: a collusion of moderate to strong shaking with a dense population living and working in largely substandard construction. Using a current population density dataset and the distribution of shaking intensity provided by the US Geological Survey (USGS) in the hours after the quake, RMS applied damage functions developed in other parts of the world and estimated approximately 250,000 potential fatalities within 36 hours of the earthquake's occurrence (RMS special report). This information was relayed to urban search and rescue teams heading to assist with the recovery. Hispaniola has not seen its last earthquake. Typically slip on one segment of a long fault zone loads the adjacent segments. The 1751 and 1770 earthquakes have been interpreted as rupturing adjacent segments of the Enriquillo fault. The section of the Enriquillo fault closest to Port-au-Prince did not rupture in the January earthquake. Furthermore, geologic studies and GPS studies of the Septentrional fault transecting northern Hispaniola indicate that the most recent earthquake on that fault occurred 775 to 965 years ago and that more than 4.5 m of slip have accumulated in the intervening time, enough slip for a Mw7.5 earthquake to recur at any time (Manaker, 2008; Mann & Prentice et al., in preparation).

Damage assessment towards a common methodology

The United Nations Institute for Training and Research (UNITAR)/ Operational Satellite Applications Program (UNOSAT), the European Commission (EC) / Joint Research Centre (JRC), the Centre National d'Information Géo-Spatial (CNIGS) representing the Government of Haiti and The World Bank / Global Facility for Disaster Reduction and Recovery (GFDRR), supported by its consultant ImageCat, performed a detailed assessment of damage to buildings. The results of this analysis have been critical in defining the rebuilding needs of Haiti.

This damage assessment relied on the use of remote sensing technology. Never before had the availability of high-resolution satellite and aerial imagery been so open and accessible. Data from different missions (World Bank-ImageCat-RIT Remote Sensing Mission (15cm optical and 2 pt/m² LiDAR), Google (15cm optical), NOAA (25cm optical), Pictometry, as well as satellite imagery from GeoEye and Digitalglobe allowed damage from the Haiti earthquake to be viewed through multiple sensors and at different times. These multi-dimensional perspectives were invaluable in understanding the magnitude and scope of damage caused by this devastating earthquake.

In addition to the advancement in access to remote sensing data, advancements in information technology, social networking and crowdsourcing techniques played an important role in both data development and damage assessment. GEO-CAN (Global Earth Observation-Catastrophe Assessment Network) emerged from this event as an unexpected resource for damage assessment. Comprised of over 600 engineers and scientists from 23 countries representing over 60 universities, 18 government and non-profit organizations and over 50 private companies, GEO-CAN identified close to 30,000 severely-damaged buildings in less than a week using very high resolution aerial imagery. Utilizing the aerial imagery, detailed damage assessments of individual buildings were conducted by comparing pre-earthquake satellite imagery to post-earthquake aerial photos. Using complementary approaches, datasets produced by the World Bank/GEO-CAN team and the UNOSAT/JRC teams were used to: 1) estimate the total number of collapsed and severely-damaged buildings in Port-au-Prince and surrounding areas; and 2) establish the overall reliability of the aerial survey damage results. In total, damage estimates were provided for 13 administrative units within Haiti.

In order to validate the aerial survey results and to also extrapolate this information to lower damage states which may not be evident from the aerial photos, the UNOSAT-JRC-World Bank/ImageCat team performed strategically-targeted field ground surveys. In addition, a separate engineering team conducted more detailed damage evaluations

1 Greater Port-au-Prince study area during Phase 2 of the damage assessment. Grid cells for distributed damage analysis are shown

2 Flight paths showing coverage of 15-cm World Bank-ImageCat-RIT Remote Sensing Mission (data captured using the RIT WASP system)

Data from different missions (World Bank-ImageCat-RIT Remote Sensing Mission (15cm optical and 2 pt/m² LiDAR), Google (15cm optical), NOAA (25cm optical), Pictometry, as well as satellite imagery from GeoEye and Digitalglobe allowed damage from the Haiti earthquake to be viewed through multiple sensors and at different times. These multi-dimensional perspectives were invaluable in understanding the magnitude and scope of damage caused by this devastating earthquake.

using very high resolution, oblique imagery provided by Pictometry. This latter dataset was invaluable in determining whether significant structural damage had occurred that did not result in the complete collapse of a structure. This information, in conjunction with the field survey data, helped to validate that the assessments produced from the aerial surveys were accurate in identifying the total number of collapsed structures and that statistically, the aerial results could be used as an index for estimating damage at all lower levels (i.e., below collapsed and very heavy damage).

The results of the joint UNOSAT-JRC-World Bank/ImageCat damage analysis (Table 1) shows that a little over 90,000 buildings were either destroyed or experienced heavy damage in the earthquake (damage classes 3 through 5). This represents a little less than 1/3 of the building inventory in the affected areas. Most of the damage occurred in the Port-au-Prince area; however, significant numbers of buildings were also destroyed in Carrefour, Delmas, Léogâne, and Pétion-Ville. Based on median floor area estimates for different occupancy uses, this damage translates roughly to over 26 million square meters in building area affected with about a third of this total associated with buildings that will have to be either replaced or significantly repaired. The total repair cost to buildings is estimated by the joint UNOSAT-JRC-World Bank/ImageCat report to be over $6 billion (US).

As part of the Post-PDNA process, the UN-JRC-WB/ImageCat group has also launched a series of workshops to capture the experiences of the different remote sensing-based damage assessments after the Haiti earthquake. The first workshop was held on 27-28 April 2010 at the United Nations in Geneva; the second on 20-21 May 2010 at the Joint Research Centre (JRC) in Ispra (Italy); and the final session at the Understanding Risk Conference, which summarized the outcome of the two previous meetings. During the conference and on the communty website, the following items were discussed:

- Presentation of the PDNA findings
- Presentation of the joint earthquake damage atlas
- Conversation on the most appropriate sensor
- Data collection techniques (this thread was started with the crowdsourcing group)
- Field validation of damage estimates
- Damage models based on remotely-sensed data
- Data integration—integrating damage data from different sensors and modalities
- The differences between satellite and aerial (this thread could be started with the remote sensing group)

Table 1. Number of damaged houses grouped in EMS-98 Damage classes per commune and dominant land-use class

	EMS-98[1] Damage Classes				
COMMUNE	5	4	3	2	1
Carrefour	2763	5905	5920	3220	35,219
Cité Soleil	1012	549	1073	576	6403
Delmas	5012	2814	5064	2881	29,478
Grand-Goâve	148	541	421	276	2175
Gressier	565	289	567	319	3436
Jacmel	214	1785	1489	857	8799
Léogâne	2220	5985	4139	2360	24,736
Pétion-Ville	2027	906	1693	708	10,614
Petit-Goâve	173	104	167	116	770
Port-au-Prince	9902	15,257	12,351	6699	62,693
Tabarre	532	365	663	383	3914
Total	24,062	34,500	33,546	18,395	188,236

Note: 1 - EMS-98: European Macro-seismic Scale (1998)

The analysis on Haiti's multiple natural hazards

Natural hazards have a history of destructive potential in Hispaniola. Some recent—and not so recent—documents have already described the causes and possible effects of seismicity, cyclones, El Niño, drought, landslides, and other occurrences. The study formed part of the Post-disaster Damage and Needs Assessment (PDNA), and aimed at:

- Conducting an inventory of hazards across the country
- Providing an assessment of imminent hazards, which mainly result from the exposure of disaster victims during the approaching rainy season and the possibility of another severe earthquake
- Summarizing recommendations for a medium- and long-term strategy for improving risk management
- Formulating an action plan consistent with the strategy developed and offer recommendations to be considered during reconstruction operations

The analysis is intended to inform a varied target audience—decision-makers, the general population, the international community, and scientists and engineers—of the natural hazards and the associated vulnerability currently present in Haiti. In view of the quantity, quality of data collected and the time available, it was necessary to organize the work in the following order of priority:

- In the very short term, that is, once humanitarian work is completed and rehabilitation has begun, determine the hazards at the temporary shelters in the Port-au-Prince metropolitan area, in other affected regions and cities in the country, and also in those areas that have been receiving and providing shelter to refugees from disaster-affected areas
- Considering the likelihood of another major earthquake striking Haiti and Port-au-Prince in the near future, paying particular attention to the possible magnitude, intensity, acceleration, and secondary effects (aftershocks, soil liquefaction, landslides and mudflows, tsunamis)
- Evaluate the hydrometeorological hazards and their secondary effects (e.g., heavy rainfall, tropical cyclones, El Niño/ENSO)

Our multiple hazards assessment of Haiti aimed at identifying the spatial and temporal scope as well as the relative intensity of the most severe natural hazards in Haiti. Evidently, the degree of precision and effectiveness of the results of this study directly depended on the quantity and quality of data available. It is hoped that the analyses presented will help to steer emergency recovery efforts and risk management, in addition to future land-use and development planning. However, these results are preliminary and are subject to review in the coming months.

The most imminent natural hazards are associated with precipitation caused by polar fronts from the northern hemisphere; in addition more rainfall is expected from tropical cyclones and waves, the Intertropical Convergence Zone, and convective and orographic activity. A new El Niño/ENSO episode could bring the tendency to delay the arrival of the rainy season and perhaps even create drought conditions. Models also indicate that El Niño activity could increase the number and intensity of cyclones; however, it is not possible to predict the route the cyclones will take and if they will approach or hit Hispaniola.

It is also clear that other natural hazards such as new earthquakes, landslides, torrential mudflows, drought, and tsunamis must always be taken into account. As a result, the vision for risk management, which includes emergency management, should be centered on a multi-hazards situation. The multi-hazards analysis perspective is meant to serve as the platform for the ensuing risk assessments. It is also required as one of the tools to understand and communicate risk, and to assist political and managerial decision making for land use planning, risk reduction and transfer, and emergency and disaster management. These are all pillars for national risk management and development planning policies.

Contributors to the session

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Ron Eguchi, President, ImageCat

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Alix Roumagnac, President, Predict Services

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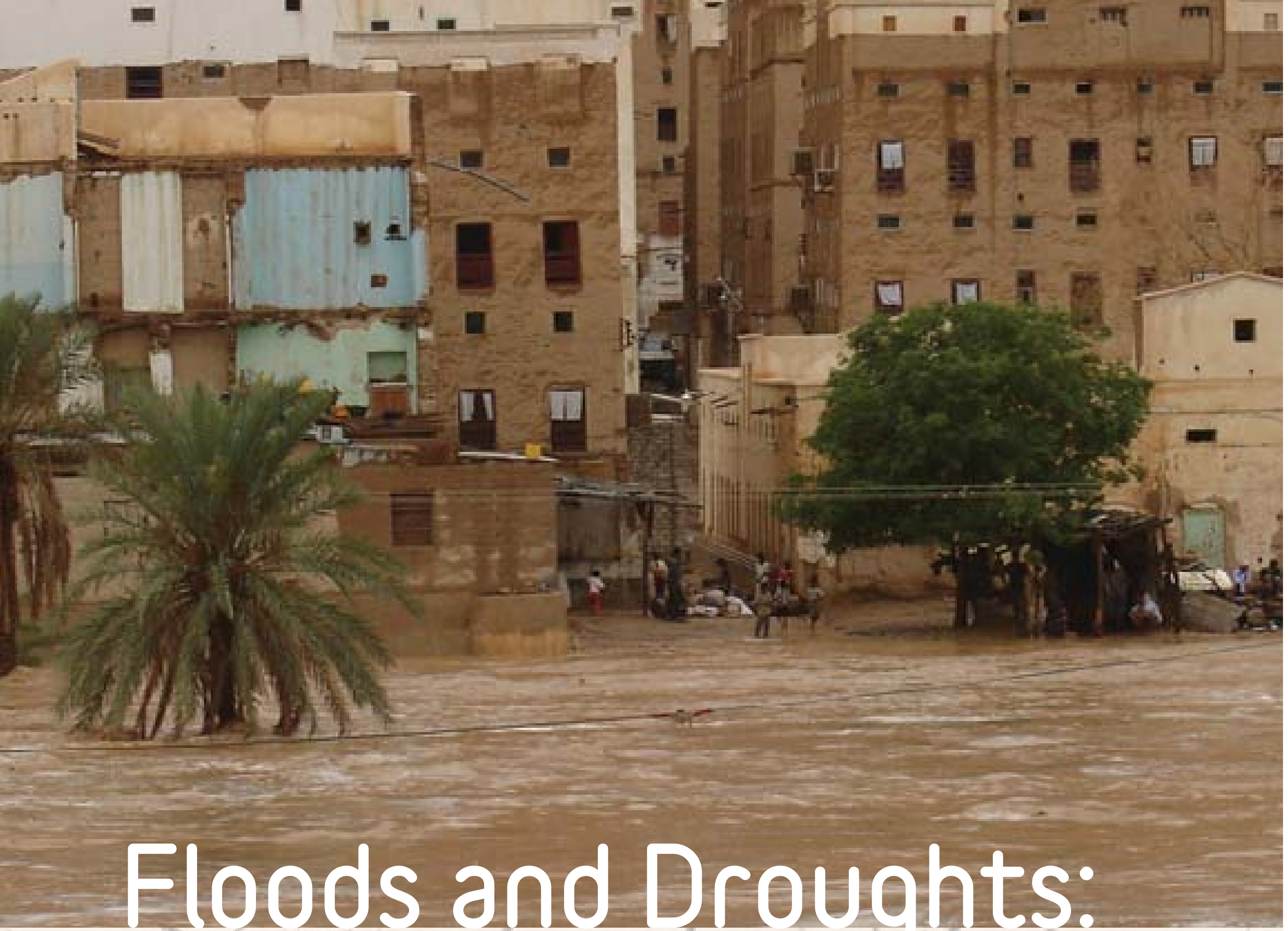


Floods and Droughts: Assessing and Predicting the Risks

Paolo Reggiani
Senior Research Scientist
Deltares

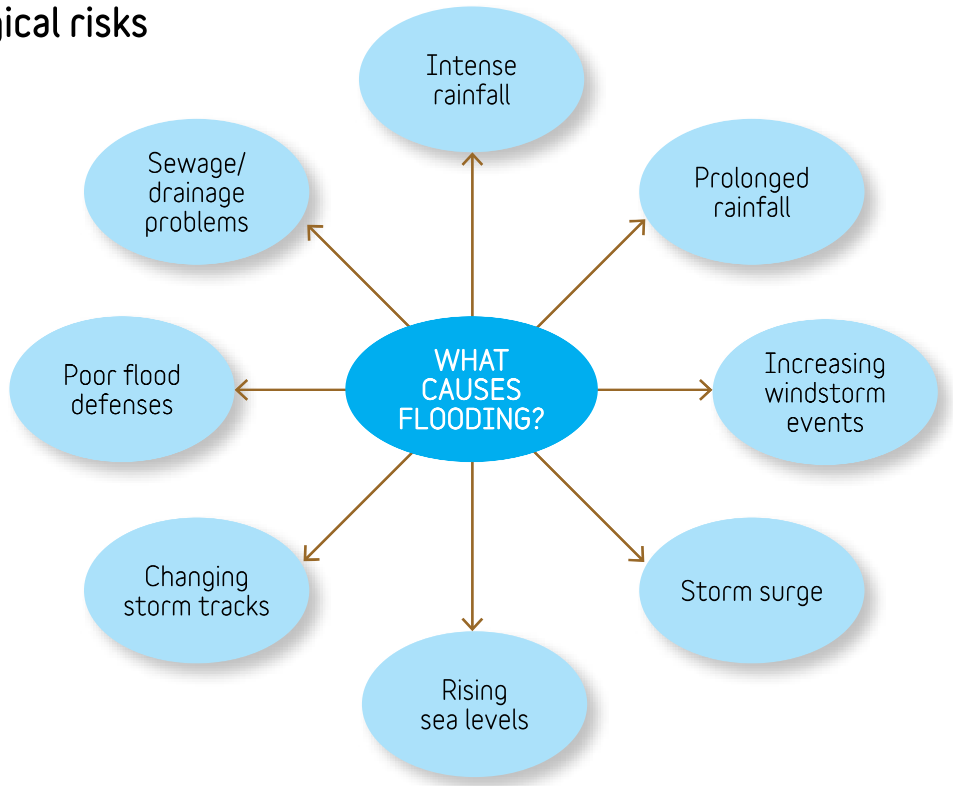
The session featured four speakers: i) Thomas Graziano, Chief of Hydrological Service, U.S. National Weather Service; ii) Rafael Oreamuno from the University of Costa Rica; iii) Ezio Todini from the University of Bologna, Italy; and iv) Rowan Douglas, CEO of Willis Research in the U.K. The focus of the sessions was clearly shaped by the content of the presentations.

The first speaker gave a presentation about Freshwater Prediction and National Warning Services at the U.S. National Weather Service (NWS). The U.S. NWS provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas for the protection of life and property and support of the national economy. Over the past 20 years, flooding has claimed on average over 90 lives per year in the U.S. and has caused damages in excess of US$7 billion annually. Floods occur throughout all 50 states, constitute a threat year-round, and cause more fatalities than any other severe weather-related phenomenon. More than half of all flood-related deaths result from motorists being swept away in their vehicles. Operational flood forecast services throughout the U.S. are provided by River Forecast Centers (RFCs). The principal services include flash flood guidance, quantitative rainfall forecasts, multi-sensor precipitation analyses, short and extended range river forecast guidance (deterministic and probabilistic), routine multi-agency collaboration, drinking water supply forecasts outreach and training, and support to weather forecasting offices and other development activities. Tom Graziano's talk provided further details on the interfaces, through which the NWS delivers warning on all aspects of their services to the end-user community.

Ezio Todini gave a presentation on the relevance of uncertainty in river flow predictions. In predicting river floods, uncertainty and risk go hand-in-hand with a high degree of subjective perception by stakeholders, he said. In his view, understanding risk implies grasping the concept of "predictive uncertainty" in flood risk mapping and flood emergency management. Todini used examples to demonstrate how understanding and assessing predictive uncertainty is the prerequisite for reducing risk as well as improving the reliability and robustness of emergency decisions. Flood risk alleviation through reservoir

Dealing with hydrological risks

- Global (climatological) drivers, local (flood/drought) impacts
- Multiple and interrelated sources: river, coastal, intense rainfall, hail, drought, subsidence
- Complex pathways: river catchments, urban drainage, coastal zones, agricultural land use
- Consideration of natural and anthropogenic influences: urbanization, land use, defences/channelisation, drainage
- Relative vulnerability: building characteristics, usage, location, insurance coverage, cropping patterns



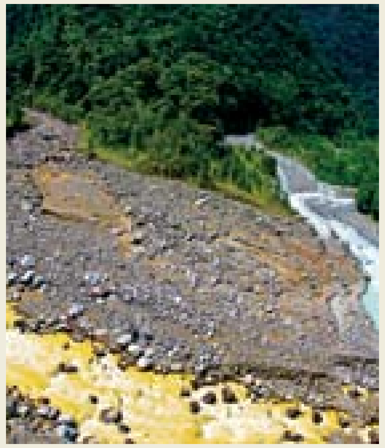


Photo: © Michael Kirkham | Dreamstime.com

Flood risk in Costa Rica

Rafael Oreamuno from Costa Rica introduced the audience to the flood risk in Costa Rica which has a negative socio-economic impact. Costa Rica is a country with a strong topographic relief whose precipitation patterns are controlled by moist air currents from the Atlantic and the Pacific. Intense topographically-driven tropical rainfall causes flooding, especially in the lower parts of the river reaches. In Costa Rica, which is part of a region with high seismic activity, there is a significant correlation between earthquakes and flooding. Earthquakes trigger landslides in the upper basins of the Atlantic Region, causing partial deforestation and instability of slopes. Because of the heavy precipitation and run-off, the natural vegetation cover has not been able to recover, leaving the soil exposed to erosion. The upper parts of the river basins then yield strong sediment loads which are transported downstream, where they are deposited in the river bed and the floodplains and restrict river flows. Rafael Oreamuno's presentation highlighted the hydrological characteristics of the most important basins, the social and economic activities in the floodplains, and the need for modeling river systems under unsteady flow conditions possibly using spatial modeling approaches and tools.

management and flood alert should be based on the assessment of the predictive uncertainty in real time flood forecasting.

The last speaker, Rowan Douglas, CEO of Willis Research Network, focused on the importance of flood prediction in the context of the business models of insurance companies. Insurance companies need to manage large quantities of capital reserves, which need to be paid out in case a disaster strikes. This requires insurers to classify the exposure of residential and productive areas to several kinds of risks and throughout a range of countries. The risks include natural hazards ranging from earthquakes, volcano eruptions, chemical accidents and fire to floods and droughts. Risk mapping constitutes a substantial task that needs to be supported through cutting-edge research in earth observation and modeling tools. While the GEM (Global Earthquake Model) initiative is already at an advanced stage of implementation, Willis is currently working with a group of expert scientists on developing a similar approach to floods and droughts. After giving a broad overview of the cash reserve structures of large insurers, Douglas outlined Willis' efforts in getting such a global flood and drought modeling initiative on track.

Contributors to the session

Rowan Douglas, CEO Global Analytics, Willis Re Chairman, Willis Research Network

Tom Graziano, Chief, Hydrologic Services Division, U.S. National Weather Service (NWS)

Ezio Todini, Chair of Water Resources Planning and of Hydrology, University of Bologna

Rafael Oreamuno, Professor of Hydrology, Water Resources Engineering and Advance Hydraulics, University of Costa Rica

Understanding risk implies grasping the concept of "predictive uncertainty" in flood risk mapping and flood emergency management.

Disaster Risk Assessment in Current and Future Climates

Olga Wilhelmi
Project Scientist
National Center for Atmospheric Research
&
Hannah Brenkert-Smith
Postdoctoral Fellow
National Center for Atmospheric Research

Floods, droughts, heat waves, and storms have always been part of human lives because they are a normal part of climate variability and local weather patterns. However, the observed trends and projected changes in global climate have the potential to alter patterns of these climatic hazards and extreme weather events.

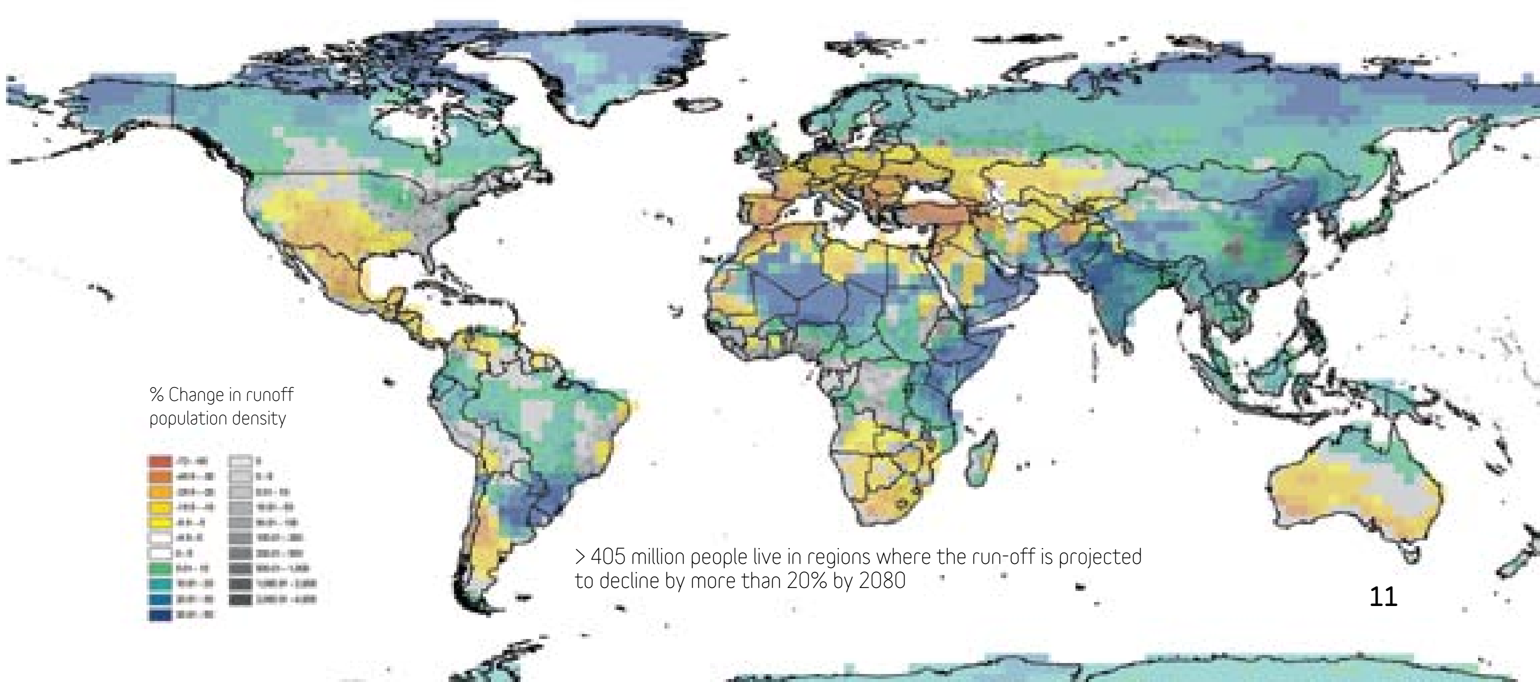
Predicting future changes in these hazards under a warming climate is a challenging task, especially at the regional and local scale. Equally challenging and important is understanding and characterizing the current and future social systems that are being affected by climatic hazards and any anticipated changes in these natural phenomena. In fact, we understand *disaster risk* as a product of natural phenomena (*hazard*) and social characteristics (*vulnerability*). This distinction between hazards and vulnerability is a critical guiding principle in disaster risk reduction and climate change adaptation. While climatic hazards cannot be prevented, the risk of and negative impacts from climate and weather-related disasters can be reduced with a focused and targeted attention to societal vulnerability.

We define *vulnerability* of the system as a function of three interactive components: *exposure, sensitivity,* and *adaptive capacity* (Wilhelmi and Hayden, 2010). Each component consists of a set of dynamic, spatially variable indicators, which in turn are affected by external drivers, such as climate change and macro-scale socio-economic trajectories (e.g., urbanization). Population growth, land use practices, and patterns of urbanization can affect *exposure* of population to climatic hazards, such as coastal flooding or extreme heat. Simultaneously, non-climatic factors such as aging, poverty, pre-existing health conditions, and migration patterns determine *sensitivity*, the degree to which a society is affected by climate stresses. *Adaptive capacity* is the potential to modify features and behaviors of social and environmental systems in order to better cope with existing and anticipated climatic stresses. In many cases, it is the starting point for an autonomous adaptation to climate change. Increased adaptive capacity is linked to increased resilience—or the ability to recover from environmental change and disruption. To better understand, characterize, and reduce societal vulnerability it is important to include all its dynamic elements in current and future assessments. Present-day vulnerability and historic record of place-specific hazardous events provide a baseline for the assessments of current risks and a starting point for building future scenarios, mitigation strategies, preparedness planning, and adaptation (both autonomous and planned). Integration of spatially varying dynamic physical and social indicators into disaster risk assessment is a challenge, particularly, because it must be systematic and, most importantly, stakeholder driven. Stakeholder involvement allows assessments not only to focus on important factors shaping vulnerability but also increase the likelihood of developing adjustments and adaptations that are realistic for any given community considering human, social, and economic capital. A bottom-up, community-based approach to risk assessment and management has proven to be an effective process with a high likelihood of sustainable results.

Past decades of disaster risk research and assessments have lead to many innovative approaches to measuring risk—for example, combining social vulnerability and multiple physical hazards. Advances in remote sensing, Geographic Information Systems (GIS) technology, and participatory GIS give us better tools and data for risk mapping and visualization across scales. In particular, GIS-based integration of weather and climate models with spatial social data allows for more comprehensive assessment of both hazard and vulnerability in a single framework. Coupling current social and environmental conditions with climate change scenarios has the potential for modeling of potential future risks with associated uncertainties. The range of uncertainty, however, may vary significantly among different regions and when moving from global to regional scales of climate projections. With development of next generation of global and regional climate models and improved methods for downscaling of climate change projections, the uncertainty will decrease. In the meantime, incorporating scientific uncertainty into risk management and climate change adaptation decision making is an important consideration.

How risk assessments are used and by whom ultimately determine the appropriate scale of risk analysis. National and global assessments provide a big picture of hazards and vulnerabilities at the scale that most closely matches projections from global climate models. Innovation in bridging global climate data with hazard mapping demonstrates changing spatial patterns of hazard events and the intersection with human settlement and development. Integrating climate projections with spatial data on existing hazard hotspots can help to identify likely future "hotspots" for hazard activity and social vulnerability (Figure 1). A central challenge of incorporating social vulnerability at this scale, however, is a lack of available and consistent data across the globe. Proxy data for social vulnerability to fill in current gaps allows the science of assessments to move forward.

Figure 1 . Spatial overlay of projected changes in run-off and current population density. Source: Adamo and de Sherbinin (2009). The impact of climate change on the spatial distribution of populations and migration, Proceedings of the Expert Group Meeting on Migration, New York: U.N. Population Division



The Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC, 2007) summarized changes in climate and weather-related hazards:

"Since 1950, the number of heat waves has increased and widespread increases have occurred in the numbers of warm nights. The extent of regions affected by droughts has also increased as precipitation over land has marginally decreased while evaporation has increased due to warmer conditions. Generally, numbers of heavy daily precipitation events that lead to flooding have increased, but not everywhere. Tropical storm and hurricane frequencies vary considerably from year to year, but evidence suggests substantial increases in intensity and duration since the 1970s. In the extratropics, variations in tracks and intensity of storms reflect variations in major features of the atmospheric circulation, such as the North Atlantic Oscillation." (page 107, Frequently Asked Questions, http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-faqs.pdf)

At a sub-national level, municipal or regional assessments allow for more generalized inter-comparison of multi-hazard risks and stresses that often include climate change. Innovative approaches are being developed to produce urban hazard scenarios through quantitative multi-risk models and explicit integration of climate change projections into disaster risk assessment. In multi-risk models (Figure 2), the physical hazards such as storm surges, urban heat waves, droughts, wildland fires, and sea level rise are triggered by the change of climate parameters (temperature, water vapor, air pressure, etc.) and interact with each other. Probabilistic methods (i.e., Bayesian logic) are used to produce quantitative hazard scenarios, including the uncertainty of each hazard.

State-of-the-art risk assessments of urban hazards include a wide spectrum of activities, ranging from climate change modeling to adaption action planning. They incorporate Geographic Information System (GIS) mapping, coastal flooding and storm surge modeling, downscaling of climate change projections to local level, urbanization, and institutional analysis and economic valuation. Work at this level provides opportunities to incorporate considerations for practical implementation (e.g., urban design and planning) based on projections of a physical hazard (Figure 3). Importantly, this research indicates that adaptation and increasing resilience must be undertaken in order to address current challenges.

Many of the countries that face the greatest challenges in managing hazard/disaster risk suffer from weak institutional capacity and lack the mechanisms required for addressing disaster risk at the community level. Poverty itself serves as a major obstacle to preventing impacts. Furthermore, weak institutional capacity limits the integration of disaster risk considerations into existing development efforts and hinders anticipatory adaptation. At the community level, local actors often lack data and information necessary for disaster risk assessment and prevention. With existing challenges in communication and limited capacity of early warnings systems, disaster risk management and climate change adaptation remain decoupled. Local and institutional foci remain on disaster response and relief rather than on anticipatory action to manage disasters and mitigate likely impacts. Moving from "Relief to Resilience" (Table 1) requires improving warning systems, strengthening vulnerability assessments, promoting resilient livelihoods, and a focus on low-cost innovations that can be undertaken in the context of limited resources. Autonomous adaptation is often already underway and more feasible at the local scale. Building institutional capacity, local capacity, and engaging community participation in risk assessments is critical to disaster risk reduction and climate change adaptation in both developing and developed contexts.

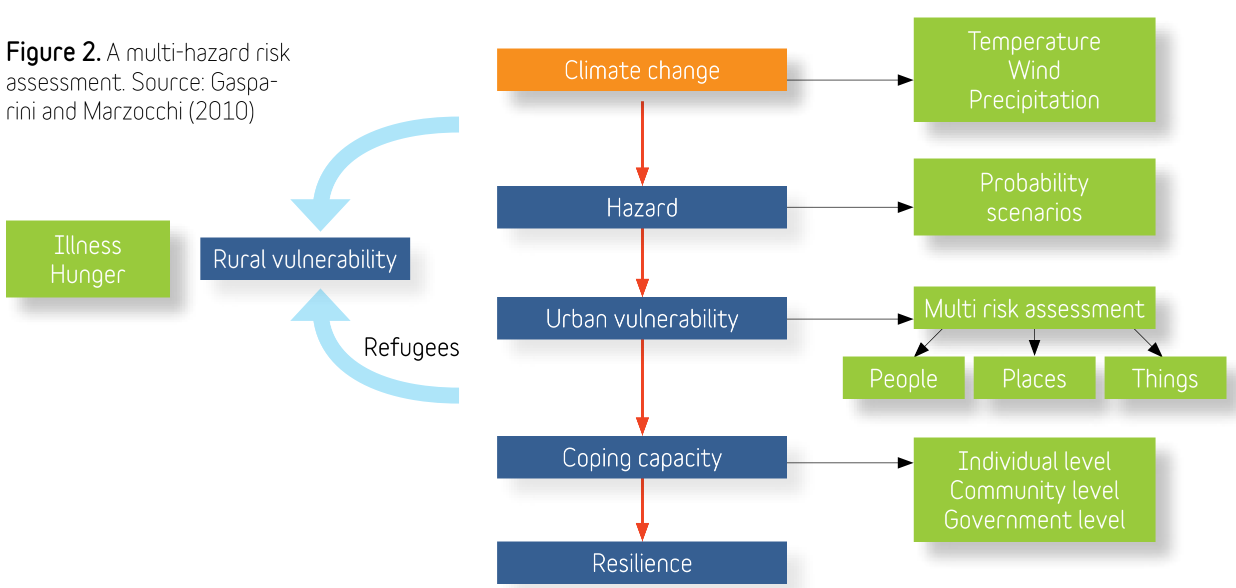


Figure 2. A multi-hazard risk assessment. Source: Gasparini and Marzocchi (2010)

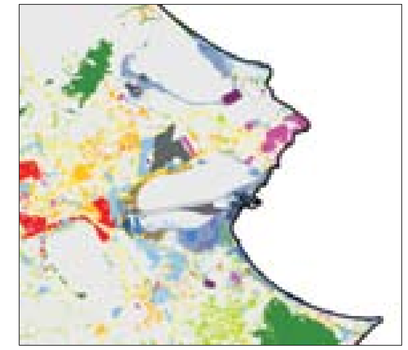


Figure 3. City of Tunis: Storm surges expected to increase to 1.34m and to cause extensive inundations of some critical and central low-lying urban areas (in blue). Source: Bigio (2010)

Table 1: From Relief to Resilience: elements of adaptive capacity and disaster preparedness in rural communities

Capital	Needs
Human	Knowledge of climate risks, conservation, agriculture skills
Social	Diversified income sources
Physical	Irrigation, seed & grain storage facilities
Natural	Water supply, productive land
Financial	Micro-insurance, varied incomes

Source: Silengo, 2010

Even state-of-the-art disaster risk assessments often lack detailed information about social vulnerability and adaptive capacity at the appropriate scale. Previous research indicates that a combination of top-down and bottom-up approaches ensure that disaster risk assessments are adjusted to local ecology but are placed in a larger picture of climate and national policies. Local-level, community-based assessments help to focus on specific cultural and social contexts, characterize adaptive capacity at household or community level and investigate options for both autonomous and planned adaptation.

Incorporation of local-level risk assessments into municipal and national level plans, with the input from climate change science remains a challenge. Further improvements need to be made in the downscaling techniques of climate change projections and better predictions of changes in hazards and extremes. A wider range of climate change projections either from multi-model or multi-ensemble climate projections is important for quantifying "worst-case" and "best-case" hazard scenarios with the range of uncertainties, that are often lacking in future planning and decision-making. On a social science side, better characterization of the dynamic factors of societal vulnerability (*i.e.*, exposure, sensitivity, and adaptive capacity) at multiple scales is needed for comprehensive assessments of risk and risk reduction measures. Overall, further research needs to focus on a multi-faceted, top-down, and bottom-up analysis of current and future risks analysis with explicit measuring and modeling of current and future hazards and vulnerabilities.

Contributors to the session

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Photo: © Photos.com

Farming Data:
What's New in Agriculture Risk Modeling?

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The development of index-based insurance and derivative contracts for agriculture has been facing technical challenges to the modeling of weather patterns that correlate with losses to farmers and find spatial and historical weather data for assessing probabilities. This session in the Understanding Risk conference presented some of the new modeling techniques the World Bank has been supporting to tackle technical challenges facing the design of index-based agriculture insurance contracts. Modeling rain, wind, and flood has been improving in the past few years, and the presentations in this session showcased new methodologies and approaches. The session's speakers represented unique leaders in the field of modeling and agriculture risk management.

Flood risk modeling

Delineating flood risk is challenging due to: (i) the difficulties of identifying ex-ante direct and indirect damages; (ii) the different types of flood risk and the fact that not all can be modeled; and (iii) the fact that agricultural assets (crops) change over time (season). Thus, in order to be able to forecast or design agriculture insurance contracts against flooding, comprehensive and complex modeling is needed. In general, flood models, even simple ones, are relatively complex. Furthermore, there are different and heterogeneous data sources for flood information, such as rainfall, river flow (speed, depth), level of reservoirs, etc. However, some considerations and advances have been developed for flood risk modeling using remote sensing to help "calibrate" flood models and assess flood impact, but that require technical capacity.

Although flood insurance is difficult to put in place (due to the localized nature of floods, water management issues, and that damage assessments are time sensitive), it can be done. However, it requires some "heavy lifting" in terms of: (i) Technical capacity (often absent in developing countries); (ii) Stakeholder coordination; (iii) Training, education, and trust building with banks, insurers, reinsurers, farmers, etc.; (iv) Investment in weather and agriculture data; and (v) Establishing and investing in a broader risk management framework (risk reduction). Nevertheless, remote sensing is a powerful technology to support both insurance and ex-post disaster relief/compensation (whether or not risk is transferred by insurance) for flood risk. It is a promising field in which (re-)insurers have showed interest.

Modeling weather in microclimates

Index-based insurance provides a potential solution for managing weather risks in hillside agriculture systems. However, the small number of farmers and size of the cultivated area, and the variability in hazard levels over short distances create great challenges to reducing basis risk to an acceptable level. Figure 2 shows the location of the farm clusters that represent agroclimatic homogenous zones. Even when some of these clusters are less than 1km apart, they have quite different agroclimatic conditions, which poses technical challenges for modelling risks and designing index-insurance schemes. (In other regions with fewer microclimates, clusters can have up to a 10km radius.) Other technical challenges to designing an index based product include: (i) lack of historical wind and rain data in the coffee-growing area; (ii) lack of quantitative impacts of past events on individual coffee trees; and (iii) lack of quantitative impacts of past events on the industry as a whole.

Furthermore, rain data is often patchy and peak events are not well recorded by manual gauges.

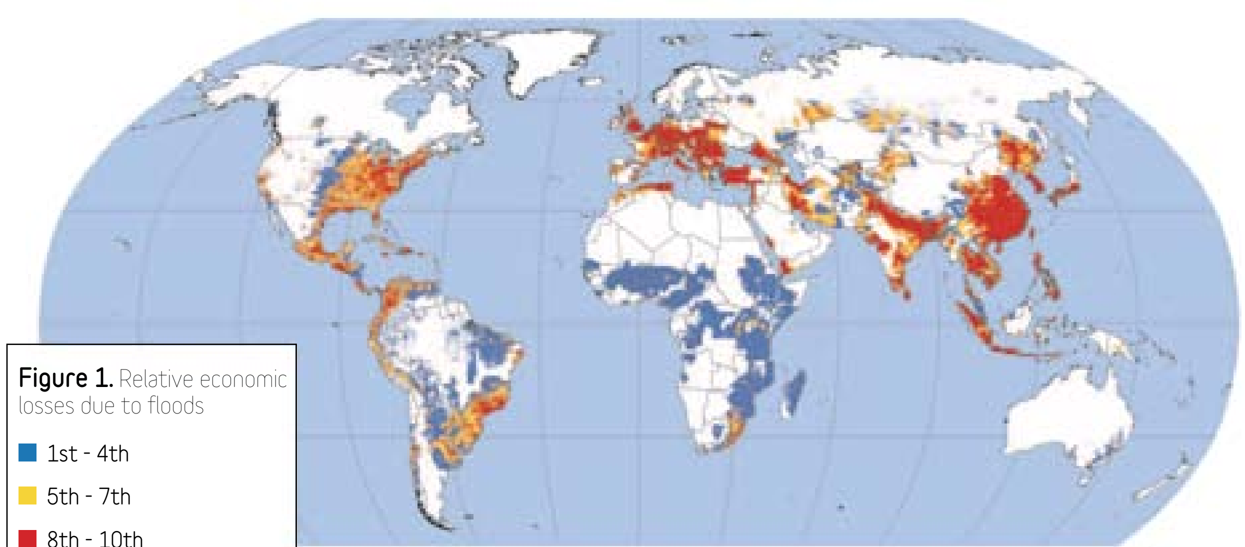

Figure 1. Relative economic losses due to floods

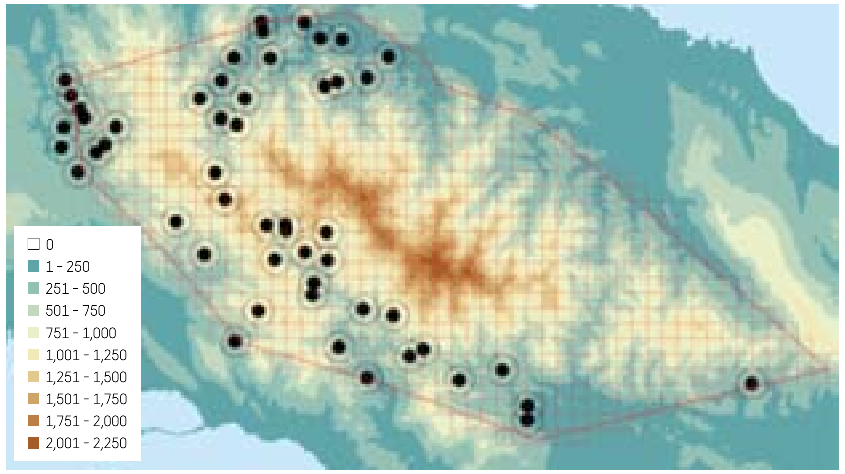

Figure 2. CGMC Blue Mountain Coffee Region Project CIB Clusters and 1km Buffer

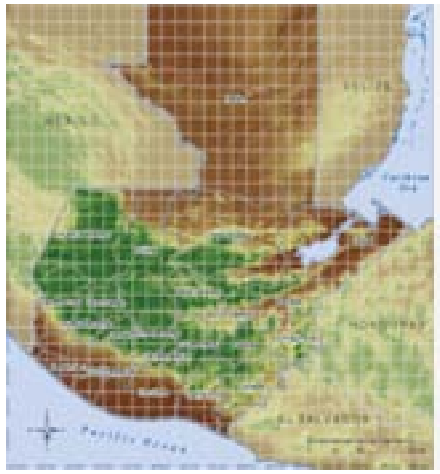

Figure 3. Guatemala's weather data grid

There is often a lack of continuity in weather records and for such mountainous and microclimate areas, satellite approaches are not suitable. The approach to modeling weather in microclimates has been to aim for a modeled rainfall to begin with, moving to gauge-controlled assessment of risks over time, or perhaps some combination of the two. In this microclimate situation, for insurance contracting purposes, there's a need to identify clusters of producers who are faced with similar hazard characteristics (homogenous agro-climatic zones); and to assess both probabilistic hazards (for contract design and pricing) and also single event impacts (for payout calculation).

Building synthetic historical data series

One of the major constraints for the development of agricultural financial management is the lack of meteorological information usually associated with: (i) limited coverage of stations; (ii) missing data in the historical records; and (iii) short historical record (e.g., recently installed stations). Using weather data grids from NARR (a long-term, dynamically, consistent, atmospheric and hydrologic database, with high spatial and temporal resolutions, generated with the numerical weather model ETA: http://www.emc.ncep.noaa.gov/mmb/rreanl/), gridded datasets can be generated with a successive correction method (Cressman, 1959) based on two predictors: Primary—Meteorological observations; and Secondary—North American Regional Reanalysis from the National Oceanic and Atmospheric Administration (NOAA) (Mesinger et al. 2006). NARR is used as a preliminary field (second predictor). Figure 3 shows the layout for the data grid produced for Guatemala, spanning the entire country.

Taking data from weather services on an "as is" basis is not recommended due to large errors. In the case of Central America, the gridded datasets were considered feasible, although the resolutions were different for Guatemala and Honduras, and, in the case of Honduras, for different variables. Gridded datasets imply smoothing of the original observations; however, risk analysis is more concerned with capturing the probabilities of losses than the exact magnitude of catastrophic events. Thus, such gridded data sets provide an important tool for filling the gaps in historical datasets for insurance purposes and risk modeling.

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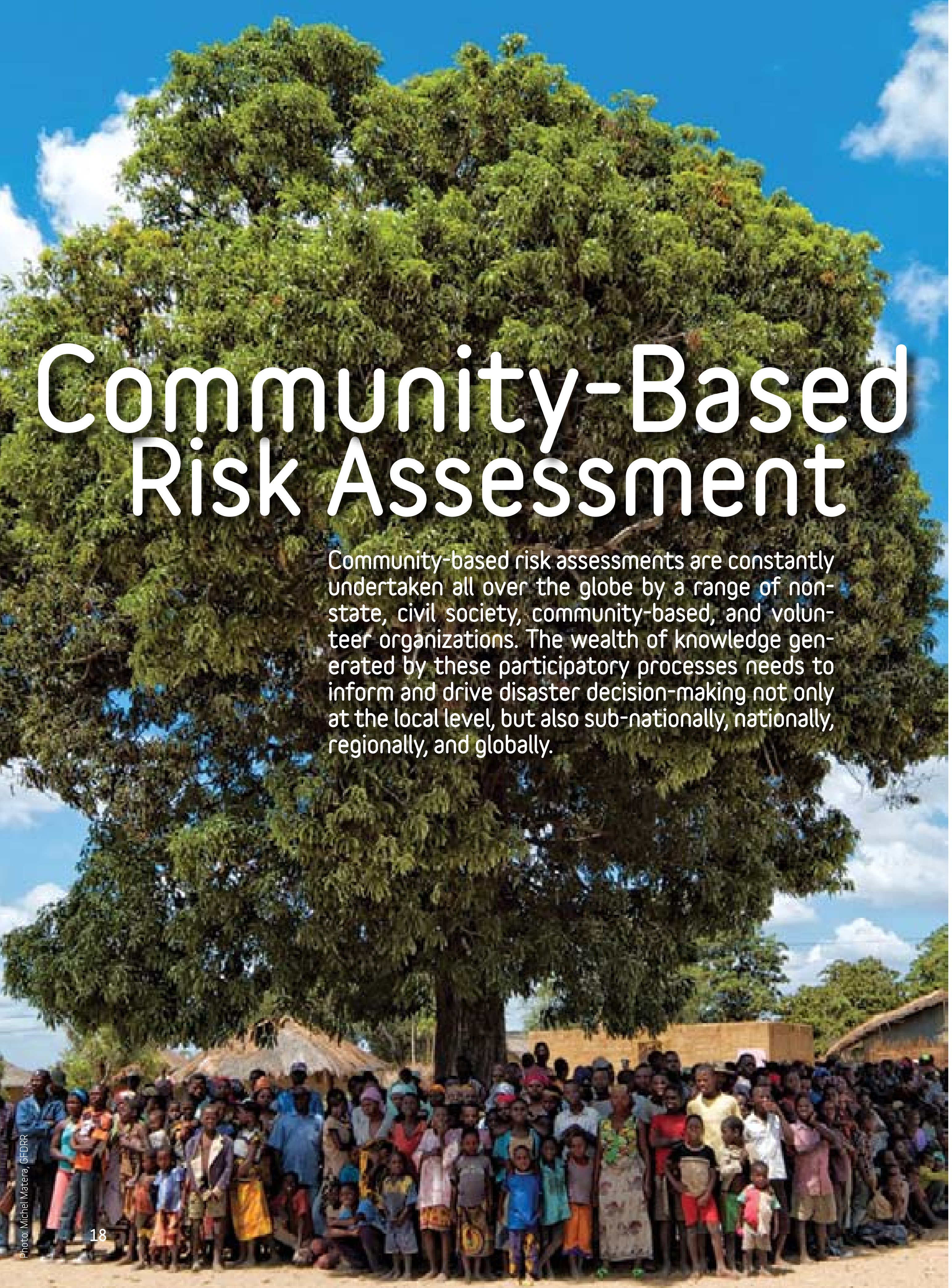

Community-Based Risk Assessment

Community-based risk assessments are constantly undertaken all over the globe by a range of non-state, civil society, community-based, and volunteer organizations. The wealth of knowledge generated by these participatory processes needs to inform and drive disaster decision-making not only at the local level, but also sub-nationally, nationally, regionally, and globally.

Photo: Michel Matera, GFDRR

Daniel Kull
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Understanding risk at the local level

The majority of civil society organizations use some form of participatory investigation to understand the level of people's exposure and capacity to resist hazards at the grass-roots level. It is an integral part of community-based disaster preparedness and risk reduction, enabling people to identify, better understand, and prioritise the risks they face, even if these are not related to natural hazards. Local risk assessment leads to the design of actions that strengthen community safety and resilience, leveraging existing capacities and if needed enabling for proper requesting and targeting of external resources. In order for community-based risk assessment to be meaningful it cannot be considered a mapping process covering only infrastructure; differing local and cultural perceptions of vulnerability and risk also need to be captured and considered.

There are a range of tools available for community-based risk assessment, allowing for flexibility of methodology to adapt to specific contexts. Generally a mix of tools and methods are used, including for example: semi-structured interviews, focus group discussions, direct observations, transect walks, seasonal calendars, historical profiles, household vulnerability assessment, livelihoods analysis, institutional and social network analysis, Venn diagrams, and collection and review of secondary data. These primarily participatory approaches also provide opportunities to share up-to-date scientific information with communities, although this requires non-technical dialogue enabling communities to find relevance with the events they experience in their daily lives.

As a mix of qualitative and quantitative approaches, community-based risk assessment tends to focus on the vulnerability and capacity aspects of risk—in fact the Red Cross Red Crescent approach is named Vulnerability and Capacity Assessment (VCA). While hazard assessments are often included in such processes, they currently tend not to utilize much scientific information. However as data availability and resolution continuously improve, technical hazard analyses are more and more becoming available at the local level. Still, local use of technical data continues to be challenged by information delivery, sometimes due to a lack of local capacity for understanding or processing scientific information.

Community-driven disaster risk management

Community-based risk assessment should not be performed simply to collect information, but rather form a core component of community-based disaster risk management. Simply by being engaged through participatory assessment processes, community awareness and understanding of risks are enhanced. Equally important, through "learning by doing" communities recognize their own capacities and approaches for managing risk. This generates a sense of ownership and empowerment, instilling a culture of prevention within vulnerable communities.

During and after a community-based risk assessment, local disaster risk management plans are often developed. These can include contingency plans, defining not only what to do in case of a disaster, but also who will be responsible for certain activities. Frequently community-based disaster risk management is implemented by volunteers and local organizations, highlighting again the need for participatory understanding and dialogue.

A variety of activities, as prioritized and defined by the communities themselves, naturally follow community-based risk assessments, for example micro mitigation projects. Partner organizations often provide small grants to support implementation, with the agreement that the community does most of the work. Technical advice, and where necessary, approvals from the municipal authority, are also solicited. Due to the participatory nature of the risk assessment, local authorities are usually involved from the beginning, ensuring agreement with any proposed risk reduction measure, and to a certain degree strengthening sustainability. In general the process can and should bring communities and local organizations into closer contact and eventual partnerships with other actors working to reduce risk, especially local government.

Underlying the flexible approach to community-based risk assessment, there is an acceptance that communities know their own risks better than any external organization or person, and community priorities can be vastly different from what supporting partners might expect. A classic example is the case of certain communities in the Middle East identifying road safety as a priority over droughts, floods, and conflict. Often community-based risk assessment leads to cross-cutting integrated disaster risk management approaches, which, being demand-driven, address multiple risks facing communities day-to-day as well as long term. The resultant multiplier effect increases impact, better strengthening overall resilience. The faux "humanitarian-development divide" is easily overcome at the local level through demand-driven community-owned programming.

Experience has shown that community-based risk assessment is a useful evidence-based advocacy

French Red Cross coordinator Miraji Salum with tsunami-warning billboard on southern Tanzanian coast

tool for improving risk management. It can highlight the often large gap between the "haves" and the "have-nots" not only in terms of welfare but also knowledge. It helps create awareness on risk reduction as well as viewing local development work through a risk reduction lens. Further it tends to create awareness in sectors outside of risk reduction, stimulating cross-sectoral engagement and identifying innovative approaches. Finally, community-based risk assessment can bring local government into the center stage of risk management, where it should in any case be highly active.

Still, some challenges remain. While it is clear that communities are active players in assessing risk, including good traditional practices, they still often have a prevailing mindset that disasters losses are inevitable. Communities are often uncomfortable with quantitative survey methods, meaning more innovative information-gathering approaches are needed. Finally, governments are sometimes reluctant to participate in or even recognize community-involved risk assessments. The question arises whether this reflects an underestimation of community capacity or concerns about accountability.

Informing policy and decision-making

In light of global commitments to engage and empower communities in risk management—including in the *Hyogo Framework for Action* —clearly community-based risk assessments must be taken into consideration in national, regional, and global decision-making and policies. Experience has shown utility in local risk information helping guide larger risk management projects, as well as providing strong recommendations for national and government and stakeholders.

There are, however, challenges in utilizing downstream information for upstream decision-making. Currently, no universal system exists to capture and consolidate this vast data from thousands of sources, although some interesting initiatives addressing this challenge exist. One innovative effort to use community information to influence higher-level decision-making is the *Views from the Frontline* of the Global Network of Civil Society Organizations for Disaster Reduction, which provides a local perspective of progress towards implementation of the *Hyogo Framework for Action*. The 2009 study consolidated 7,000 "views" from over 400 organizations in 48 countries, concluding that:

- Nationally-formulated policies are not generating widespread systemic changes in local practices;
- Resources are scarce and considered one of the main constraints to progress although there are resources at a local level which remain untapped;
- The foundation for building resilience is people's awareness and understanding of the risks that they face; and
- Climate change provides a threat and an opportunity to address underlying risk factors and raise external resources and political commitment for building resilience.

Moving forward

Recognizing that community-based risk assessments form the starting point for lowering risks in communities, assessments should be leveraged and strengthened to form knowledge-sharing mechanisms.

Assessments must be based on a common language and understanding in order to become the basis for dialogue. The most meaningful outcomes should also lead to greater accountability towards communities at risk.

The utilization of community-based risk assessment for upstream decision-making requires more than just information consolidation and transfer; it also requires political will. Community-based risk assessment adds value at the local level through empowerment, social and political inclusion, and local ownership of disaster risk management. Assessments need to be embedded in wider social processes that are of clear benefit to communities who are expected to participate; otherwise they will not see a benefit and grow cynical of simply being information providers. The assessment process can have a role in creating social demand and political space which encourages local and national government to work more closely with communities and local actors. Upstream decision-makers however need to recognize and value community inputs; otherwise the process will be ineffective.

New technologies, as discussed in some of the other sessions of the Understanding Risk conference, are providing new opportunities for performing, consolidating and communicating community-based risk assessment. Corporate partnerships, whether related to these new communication and data processing technologies or not, are seen as potential vehicles for leveraging engagement of all actors. If the private sector recognises potential added value, both vulnerable communities and governments alike are more likely to become engaged.

> Equally important, through "learning by doing" communities recognize their own capacities and approaches for managing risk. This generates a sense of ownership and empowerment, instilling a culture of prevention within vulnerable communities.

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Making Ends Meet: How Communities Can Use Risk Assessment Results

Lauren Augustine
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Today, text messages, tweets, smartphone apps, and social networks, not to mention 24-hour cable news cycles and countless other media platforms, deliver information to people in the critical times during and after a disaster.

These and other technological innovations in risk identification and risk assessment advance the rate, quantity, and maybe even the quality of information that is transmitted and received during a disaster.

The "Making Ends Meet: How Communities Can Use Risk Assessment Results" session, hosted by the Disasters Roundtable (DR) of the National Research Council of the U.S. National Academies, posed the question "How can 21st century technological innovations be used in the pre-disaster, during disaster, and post-disaster phase?" The session was an interactive discussion with panelists and about 50 participants who probed ways to satisfy the need to get information transmitted, received, and understood in ways that reduce risk to people and communities.

The 90-minute session was divided into four segments: (1) brief opening statements from each of the invited panelists; (2) three 20-minute panel discussions on pre-, during-, and post-event disaster phases, respectively; (3) ample time for questions, answers, and discussion among panelists and participants; and (4) creating an agenda for actions that can advance people, organizations, and communities to reduce their risk and be more resilient in all phases of disasters.

The session included four panelists, Ana Lucia Hill, Disasters Manager, Mexico City, Mexico; Frantz Verella, former Minister of Public Works, Port-au-Prince, Haiti; David Ropeik, American journalist and consultant specializing in risk communication and author of "How Risky Is It, Really?"; and Timothy Tinker, strategic and technical communicator, Booz Allen Hamilton, Washington, DC, U.S. The panelists brought forth a range of expertise that included perspectives from the media, private sector, federal government officials in disaster management, and public health.

Panelists and participants engaged in a conversation structured around four overarching questions in the three phases of disasters, pre, during, and post. The questions were posed and discussed in three 20-minute panel segments. The questions were:

1. How do people behave when they receive risk information?
2. What is the role of social networking in communicating disaster risk information?
3. How do technological innovations in natural hazard risk assessment help reduce human suffering?
4. How can technologiogical innovations help communities use risk information and become more resilient?

Ms. Hill spoke of the importance of education in the pre-disaster phase. She said that educating people will help them make "wise decisions". In the pre-disaster phase, it is also important to put into place early warning systems. One of the early warning systems that Mexico City employs is a message (SMS) to phones with a distinct sound in the message. The sound that is played in the message alerts local people that the message is important and that it should be read immediately. During a disaster, Ms. Hill said it's important to make sure that there is a plan in place so disasters are handled appropriately, and emergency situations are eliminated, even if 21st century technology isn't working. Ms. Hill said that tools like Twitter (twitpics) can be useful, but she issued a caution, as well: the quantity of information transmitted via social networking sites may not be of high quality or reliability. After disasters, it is important to utilize the technology that is available to the community, such as cell phones and televisions, to gather information or call for help. Ms. Hill closed with an illustration of how the act of communicating information—even if it's done effectively—is not the same as understanding how that

information is received, nor is it the same as understanding what people will do with the information upon receipt. A story that Ms. Hill shared was about an event that forced people to evacuate their homes. The evacuation instructions were specific in instructing evacuees to "take only necessary items." One of the evacuees, a woman, brought her washing machine to the shelter. When questioned about this as a "necessary item," she replied that the machine was necessary to her livelihood, and she would need it and the work she can do with it no matter where she is.

Frantz Verella spoke of rebuilding a more resilient Haiti and shared many stories with audience members. During the pre-disaster phase, Mr. Verella said that it is important for people to believe a disaster is eminent, "if you believe, you will do what is needed [to protect yourself before a disaster occurs]". He spoke of the failures of common control systems during disasters, when roads are blocked, communication systems are down, and power is out. Mr. Verella told how during the recent earthquake in Haiti the Haitian Prime Minister could not get in contact with the President using the available technology, so Mr. Verella had to drive by motorcycle to the President's house. Upon reaching the President, Mr. Verella found that the President had been trying to get in contact with the Prime Minister's head-quarters—this is the equivalent of the U.N. military central in Haiti —but had been unsuccessful. So the President asked Mr. Verella to go to the Minister's headquarters to see what the situation was. Once Mr. Verella reached the headquarters, he found that the building had collapsed, destroying all of the Minister's control systems. From this story and others, Mr. Verella shared three key points:

- Systems for reducing disasters must be organized on density connected networks instead of a hierarchal tree because if one link fails in a hierarchal tree, the whole system fails. A density connected network is two-way communication—not just output —that facilitates an on-going conversation.
- There is a need for emergency locations outside of disaster threatened areas with power, energy sources, and communication.
- Communications and their infrastructures must be redundant and people who are normally not included in communications—youth group leaders, religious leaders, women in markets—must be included in disaster communication and protocols.

Author and risk communication consultant David Ropeik spoke about how the brain works in the different phases of disasters. Mr. Ropeik said it was important in a pre-disaster period for authorities to speak about emotions that may arise when a disaster strikes, so people can expect certain feelings and be better prepared to respond in emergency or life-threatening situations. The transmission of stress-related neuro-chemicals in the brain can supersede logic and reason, so a reliance on technology or a device will work best when the technology is familiar or has been used or practiced before the risky situation occurs.

Timothy Tinker, a strategic and technical communicator, said everyone in an enterprise needs to be ready for a disaster, understand the role each person will play, and build resilience. He emphasized the need for individuals to be vigilant by being in a "skilled state of mind." He said that people must be able to decipher if the threat is real or perceived and then act accordingly. Mr. Tinker showed excerpts from videos and asked audience members what they would do in different situations. One of the new ways to share disaster information is the "citizen reporter". The individual at the scene conducts a scene analysis, may interview people, gather information and photos, and write a piece on what he or she saw, or share a clip of the disaster scene. Mr. Tinker believes that there is an opportunity to adapt to these new and innovative ways to communicate and use new technologies.

After the panelists made their statements and presentations, participants were asked to write down important action items that, based on their experiences, would reduce risk to people and communities in the different phases of disaster preparedness, response, and recovery. What resulted was an agenda to reduce risk to people and communities. The ideas that participants contributed are as follows:.

Pre-Disaster Phase

Participants suggested that emergency managers, citizens, and governmental officials could help build resilience

- Build collaborative relationships at the community level.
- Initiate a warning system in an emergency similar to the siren alert that Mexico uses.
- Those with cell phones should download applications like "I'm OK," and new cell phones should come equipped with the application. (The application allows you to tell your family and friends that you're OK in a disaster situation).
- Identify community leaders and engage them to participate in decision-making processes by preparing communities to be able to identify hazards and develop and practice emergency plans.
- Engage community members to be empowered through building trust and control at the individual level to lead to more community preparedness.
- Support the development of resilient social networks that are the foundations for response efforts.
- When communicating about hazards and risks, inform people about what actions to take, but also tell people what they may feel. More strongly connecting the emotional expectations of an emergency to the actions that people can take increases the control each person has in risky situations.

During a Disaster

Participants suggested the following key things to build resilience of people and communities

- For people to have real, achievable things to do, so they feel that they have some control.
- For emergency managers to receive information from the disaster site, and for emergency managers be equipped to receive information via mobile devices that have social networks and other applications enabled (e.g. picture mail/text messaging).
- For emergency managers and civic leaders to coordinate and communicate with citizens.
- Bottom-up communication and not just top-down communication systems.
- Wide-spread usage of cell-phone applications like "I'm OK."
- For citizens to be able to communicate to emergency managers through text message, share videos, and pictures.

Post-Disaster Phase

Participants suggested these key things to build resilience of people and communities

- Use the disaster to design and secure strategic investment in long-term infrastructure construction.
- Evaluate lessons from the recent disaster response, and build from those lessons more robust or alternative plans.
- Design and engage systems for advance disaster recovery and rebalance.
- Secure regional investment in risk reduction to help protect against future disasters.

Contributors to the session

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RISK Perception and Communication

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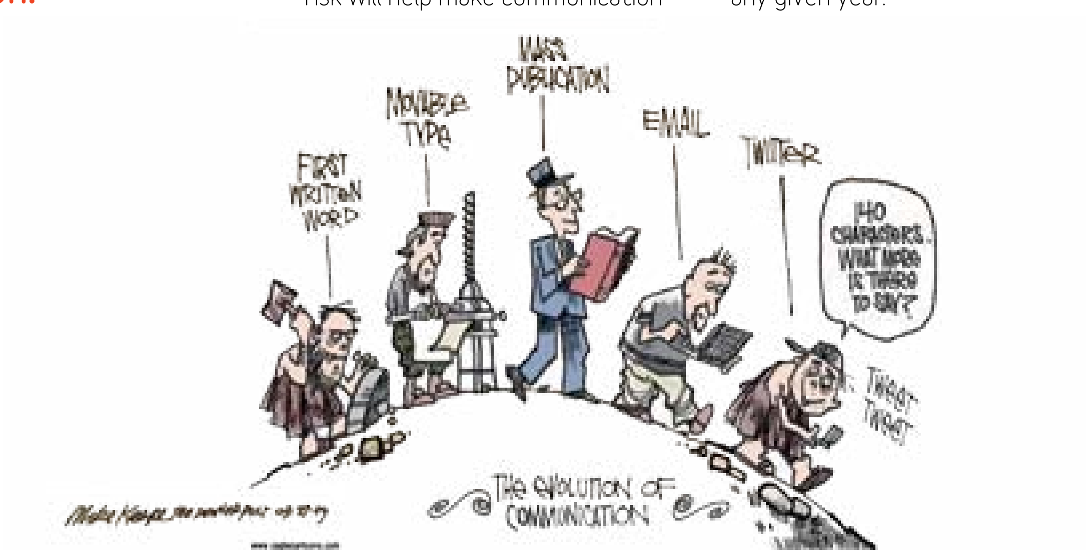
We are essentially hardwired to use emotion before fact in responding to a risk situation.

David Ropeik's presentation on the Psychology of Risk began by exploring the audience's understanding of how to define risk. His exchange with audience members highlighted two aspects of risk perception: risk involves the probability or chance that something bad will happen, and risk is always subjective; what I perceive as bad may not be the same for others.

He then gave a compelling portrayal of how the architecture and chemistry of the human brain affect our perception of risk. We are essentially hardwired to use emotion before fact in responding to a risk situation. Stressful situations trigger our "fight or flight" response, heightening the influence of instinctive and emotional responses, compared to the use of reason. Understanding the psychology of risk will help make communication practitioners more adept at risk communication, which David defined as: "Actions, words, and other interactions that incorporate an understanding of and respect for the affective perceptions of the information recipients, intended to help people make more informed decisions about threats to their health and safety."

Jessica Ludy, speaking about public perceptions of flood risk in the United States, presented some fascinating data from a study conducted by UC/Berkeley on perceptions of risk among people living behind flood levees in California. In the first instance, there was widespread misunderstanding about the commonly used terms "100 year levees" and "100-year flood," which refers to the 1% risk of a flood in any given year.



Some people surveyed believed that the "levees were made to protect us for 100 years," and that "the last flood came in 1950; the next one will be in 2050." Even though their risk is considerably higher, 60% had never been informed about flood risk, 60% rarely heard about flooding, and 6% had ever spoken with a real estate agent about the risk. Only 20% had flood insurance, and only 13% took precautionary measures (such as having an evacuation plan, putting their valuables on the second floor, and having a disaster supply kit). Most believed that they would not be allowed to live behind a levee if it were not safe. Jessica identified the needed next steps in research as gaining a better understanding of "protection motivation"—what will motivate people to take protective action in this situation of low probability but potentially catastrophic risk.

The final presentation at the panel was given by Todd Khozein from SecondMuse, the company that organized the interactive Website for the Understanding Risk conference. As illustrated by the slide from Todd's presentation, new media like Twitter are often not taken seriously as tools for social change. But he described one very clear illustration of what a powerful tool it can be. Actor and celebrity Ashton Kutcher challenged and beat CNN to enlist one million followers on the social media platform Twitter in April of this year. To celebrate his victory, Kutcher is sending 10,000 mosquito nets to help the organization Malaria No More fight malaria in Africa, which will protect 20,000 children from this disease. Kutcher further helped Malaria No More raise awareness for World Malaria Day on April 25th by galvanizing his Twitter army to spread the word about how the world is fighting—and winning—the battle against the disease. As this Twitter experiment shows, new media can enable millions of individuals to be part of making sweeping, global social changes and saving lives.

In reflecting on my own experience working on risk communication for avian influenza and H1N1, a recent review of the global effort to reduce the impact of H1N1 ("The Price of Poor Pandemic Communication," Thomas Abraham, BMJ 2010; 340:c2952) brought home some of the same lessons that our panelists presented. The review concluded: "The principal failure was that instead of using the tools and principles of risk communication to create public understanding of the risks posed by a pandemic, experts and policy makers used another form of communication, advocacy, which is intended not so much to create understanding but to persuade the public to take certain actions."

The article pointed out that communication messaging focused on the severe human and economic costs that could result from a pandemic that could be a catastrophic event. When the pandemic turned out to be much milder than expected, the gap between reality and prediction produced a public backlash, with people questioning the competence and motivation of public health agencies and a suspicion of the advice coming from them. "Risk communication to create a public dialogue on the risks of a pandemic, rather than advocacy based on appeals to fear, would have been the correct approach," according to the author.

Abraham's conclusion, very consistent with David Ropeik's perspective, provides an apt summary of one of the main lessons to take away from our discussion of risk perception and risk communication. Risk communication is "about building a shared understanding with the public, about the nature of a risk and the measures needed to respond to it through dialogue. It is not about trying to persuade people…the aim of risk communication is not for the audience to accept the views or arguments of the communicator, but to raise the level of understanding so that all those who are involved are adequately informed within the limits of available information."

Contributors to the session

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Photo: © Photos.com

Black Swans and White Whales

Kenneth L. Verosub
Department of Geology
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The goal of this session was to use low-probability events that have the capability of wreaking great havoc on human populations to help us understand similar events that occur more frequently. In the online discussion that led up to the session and in the session itself, we found it useful to frame the discussion in terms of "black swans" and "white whales."

In European society, as far back as Roman times, the black swan was symbolic of something that could not possibly exist. Then in 1697, the Dutch explorer Willem de Vlamingh discovered black swans in Australia, and the certainty about their non-existence came to an abrupt end. Knowledge of the existence of great white whales (à la Moby Dick) probably goes back to the time humans first started venturing out into the open ocean, but white whales have always been recognized as being extremely rare. Thus, black swans can be used as a metaphor for events that radically change the way we look at the world while white whales can be used as a metaphor for very low probability events that we know exist.

One of the points that emerged from the online discussion was that the boundary between black swans and white whales was not as clear as it originally appeared. For example, the destruction of the Twin Towers of the World Trade Center on September 11, 2001, is probably that first example that comes to mind as a black swan event. And yet, various precursory events, from suicide by plane to the terrorist take-over of aircraft had already occurred and could have been used to develop a scenario very much like the one that took place at ground zero. So from that perspective perhaps 9/11 could be viewed as either a black swan or a white whale event. Similarly, two apparently black swan events that occurred during the course of the on-line discussion, the disruption of air traffic throughout Europe due to the eruption of the Eyjafjallajokull volcano in Iceland (background photo) and the oil-drilling rig explosion and subsequent massive oil spill in the Gulf of Mexico, came as no surprise to a moderately large segment of both the earth science and geotechnical engineering communities.

That raises the question of whether in this age of almost unlimited access to knowledge and unlimited dissemination of news there is any event, natural or human-made, that some credible person somewhere has not anticipated. The trick in terms of understanding risk is then not so much to identify possible black swan events as to determine the relative importance that we should place on an array of them. One aspect of dealing with this is to find ways to calculate correctly the probability of occurrence of particular events. However, dealing with either nature itself (in the case of natural disasters) or with human nature (in the case of accidents and attacks) does not lend itself to simple probability calculations.

Compounding this problem is the fact that even if we can build a statistical model for a set of black-swan or white-whale events, the distribution may be fat-tailed, rather than normal or Gaussian. Fat-tailed means that low-probability events can have impacts that are much higher than one otherwise would expect. For example, people in the 95th percentile of height are only slightly taller than people in the 90th percentile, whereas hurricanes in the 95th percentile can be two or three times more devastating than those in the 90th percentile. Dealing with fat-tailed distributions statistically is far more difficult and far less understood than dealing with normal distributions. In addition, apparently independent low probability events can actually be correlated, as when very heavy rainfall produces both flooding and high winds.

Beyond the mathematical issues of dealing with black swans or white whales is the problem of getting organizations to respond to the appropriate risks and at the appropriate level. Many organizations are ill-configured to do this. Often the bureaucratic response to a black-swan event that has occurred is to develop elaborate rules and procedure for dealing with the past event rather than to use that event to develop a flexible and adaptive response that will work with other, somewhat different black-swan events. The more bureaucratic an organization, the more likely it is that messengers are ignored or even punished, and the less able the organization will be to respond effectively. On the other hand, organizations that have a generative safety culture are open to signs of trouble, encourage messengers, and are able to respond effectively.

The complexity of certain types of phenomena also makes it difficult to develop adaptive responses. For example, the threat from volcanic eruptions involves more than just the extrusion of some magma or the ejection of some volcanic ash. In the past 200 years, we have seen volcanoes that emitted fluorine gas which killed large numbers of people and livestock in Iceland, that created poisonous atmospheric conditions in Europe, that buried entire cities under mudslides in South American, that "burped" out a thick layer of carbon dioxide which killed people and animals, but not birds, in Africa, and that produced global cooling which led to famine in many parts of the world. Preparing for all of these or even a subset of them is a very difficult challenge.

If a massive earthquake occurs in the middle of the largely uninhabited Taklimakan Desert in China, is it a critical event? Is the perception correct that the earthquake risk in Washington, DC is low, or simply the result of an anomalous period of low seismic activity over the past 300 years?

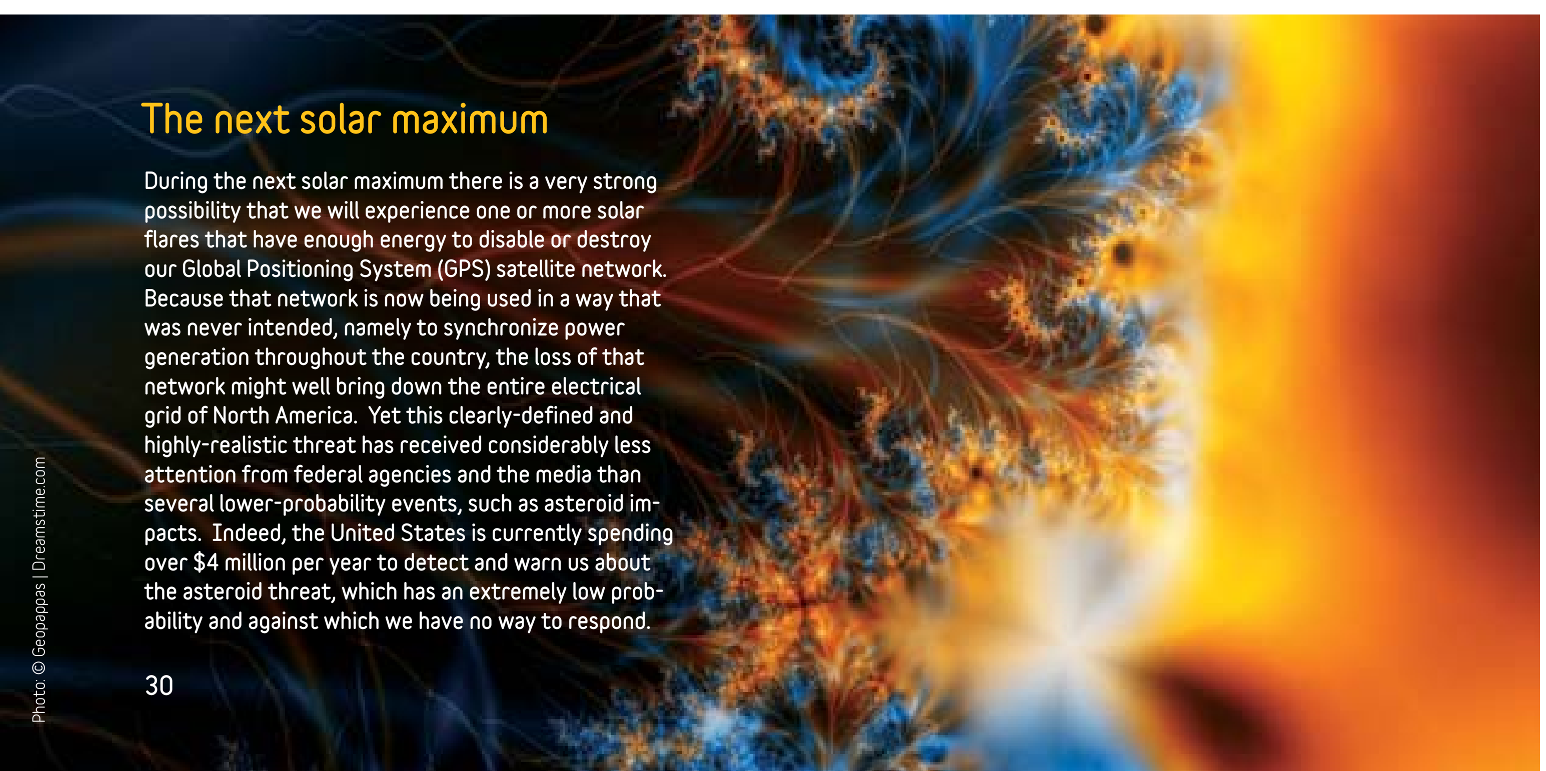
People's perception of the relative threat posed by different types of risk adds to the challenge of dealing with black swans and white whales. These perceptions are often at variance with either the actual probabilities of occurrence and/or magnitudes of the impacts.

The solar maximum story also demonstrates how improvements in technology can increase the impact of a particular event. Other factors that can influence the impact are location (If a massive earthquake occurs in the middle of the largely uninhabited Taklimakan Desert in China, is it a critical event?) and the inadequacy of the historic record (Is the perception that the earthquake risk in Washington, DC, is low, correct or simply the result of an anomalous period of low seismic activity over the past 300 years?) These various examples highlight some of the gaps and shortfalls in our ability to understand and respond to low-probability events. On the mathematical/statistical end of the scale is the need for better methods for estimating the probabilities for these events, including the ability to work with fat-tailed distributions and interdependent phenomena. We also need new tools that allow us to deal with higher levels of complexity and with threats that represent a continuous spectrum of threats, rather than distinct phenomena.

We also need to develop organizational structures that can avoid the temptation to focus on endlessly chasing the previous black swan and focus, instead, on using past experience to develop adaptive strategies for dealing with an array of future black swans. We need to learn how to make rational choices between different types of risks, based on probability and impact, rather than on media attention and public perceptions. And we need to learn how to transfer that understanding—reached through engagement of all the stakeholders—to the decision-makers who ultimately approve public policy and set funding levels.

On the positive side, there are new approaches that can be used to help us identify and evaluate risks, such as crowdsourcing for warnings and reporting, and that allow us to better understand and evaluate the nature of threats, such as visualization techniques.

And finally it is important to understand that we can't identify and defend against every black swan imaginable. We need to focus on what might be called existential threats as opposed to garden variety threats. But we can never anticipate every risk, every black swan, so the best strategy might well be to learn how to manage risk generically through a combination of preparedness, monitoring, and vigilance.



The next solar maximum

During the next solar maximum there is a very strong possibility that we will experience one or more solar flares that have enough energy to disable or destroy our Global Positioning System (GPS) satellite network. Because that network is now being used in a way that was never intended, namely to synchronize power generation throughout the country, the loss of that network might well bring down the entire electrical grid of North America. Yet this clearly-defined and highly-realistic threat has received considerably less attention from federal agencies and the media than several lower-probability events, such as asteroid impacts. Indeed, the United States is currently spending over $4 million per year to detect and warn us about the asteroid threat, which has an extremely low probability and against which we have no way to respond.

Photo: © Geopappas | Dreamstime.com

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Extraction of Exposure Information from Earth Observation

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Satellite images differ based on a number of parameters of which two, the landscape detail and the area covered, are taken into account when mapping and quantifying exposure. In general, imagery that provides less detail covers large areas of the Earth surface, while imagery covering relatively small areas provides higher detail. Coarser imagery covering large areas is typically used to map countries or regions while finer scale for high resolution imagery and aerial photography are increasingly used for mapping exposure at city or local levels.

The unique characteristic of aerial and satellite images—also referred as Earth Observation data—is their synoptic view of the Earth's surface (Fig. 1a). These Earth Observation images are increasingly used to map physical exposure (Fig. 1d) because they can show the entire spatial extent of the city or settlement in a region. Satellite images differ based on the detail they show and the area they cover. Aerial photography and Very High Resolution (VHR) satellite imagery—that of resolution of 1 x 1m or better—allows for identification and mapping of buildings (Fig. 1b) and thus the building stock (Fig. 1.d).

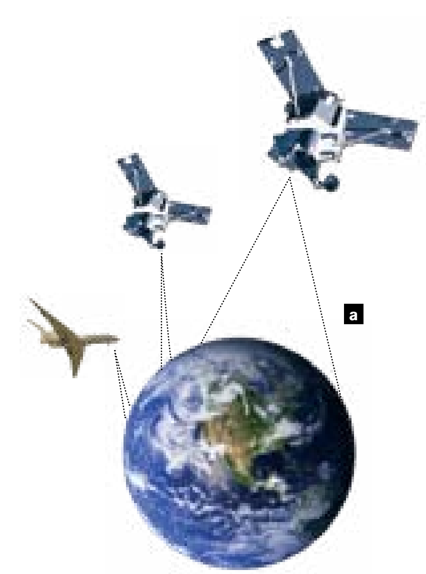
VHR satellite imagery is increasingly available from commercial image providers. The coarser resolution imagery (Fig. 1.c) is often freely available to the research community and civil society and is typically used to map large areas. Satellite imagery is often preferred to aerial photography because of its global availability and un-restricted use (http://en.wikipedia.org/wiki/Satellite_imagery).

A range of airborne and satellite-borne sensors provide oblique looking images that can be used to characterize the built-up or building stock. Nadir looking imagery has been proven of great benefit for the accurate spatial mapping of buildings. Side looking images depict building facades and thus are used to derive information on the quality of building as well. The oblique looking imagery captured in stereo is also used to derive the buildings height as well as landscape topography. Newer technologies such as LiDAR (Light Detection and Ranging), provide detailed building heights and topography information, and very high resolution radar imagery is also starting to be used for built-up mapping, building height, and stock assessments.

Exposure data

Medium resolution satellite imagery has been used to produce land cover maps and land use maps. Continental land cover maps have been developed for the United States, for Europe, and part of Africa as well as India. These land cover maps include one or more "artificial surfaces/urban" classes. These classes relate to the density of manmade structures in settlement and urban areas and can be used as a basic surrogate measure for physical exposure in country or continent-wide assessments. Urban land use maps focus on cities and are more detailed since they generally provide a larger number of built-up sub classes required by more sophisticated classification schemes. While land cover classes only identify the presence of the built-up, urban land use classes typically contain attribute information on the built-up density as well as the use of buildings and other urban parameters that are independent from imagery. The land cover and land use classifications derived from medium resolution satellite data are usually insufficient when the goal is to differentiate risk, or if expected damages are to be quantified.

Assessment at the individual city levels requires the use of VHR imagery (Fig. 2a) that provides information on buildings and other manmade objects including transport infrastructure. Not only built-up areas but also the building stock can thus be extracted as quantitative information which is



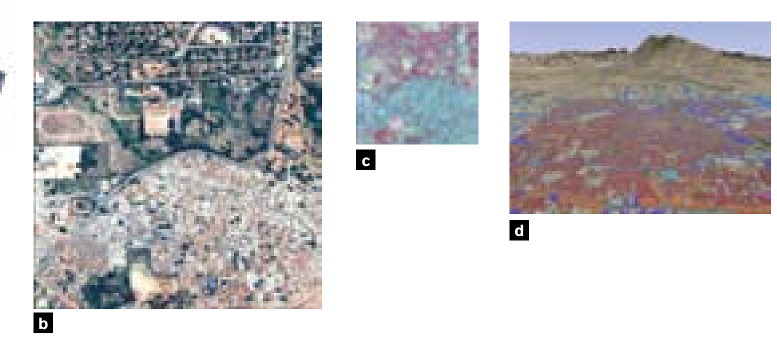


Figure 1: Earth Observation (a); imagery covering 1km^2 of Nairobi: high resolution (b) and medium resolution (c); and an example of derived exposure datasets for Sana'a (d)

Figure 2: The figure shows a 250 x 250 m large area collected over Sana'a and the derived exposure products (a), point assessments (b), building footprint map (c) and building volume map (d)

more suitable for disaster risk analysis (Fig. 2c-d). The accuracy and precision of the resulting information depends on the extraction techniques, which are in turn related to the cost of processing.

Point assessment (Fig. 2b) is a basic approach to creating an inventory of structures that is typically accurate and fairly rapid. Point assessment does not provide information on size of buildings, which is important, for instance, to estimate their value. Any building density estimation based on point data could be severely biased. Simple detection and labeling are still often used for providing rapid assessment of the housing stock especially in a post-disaster scenario when the number of damaged buildings needs to be measured against the total number of buildings.

Building footprint (Fig. 2c) maps yield useful measures for risk assessment such as density, space between buildings, size of buildings, or proximity of buildings to potential hazards. Delineating each individual building or structure is more time consuming than point representation but supports a broader range of applications.

The most precise building assessment is obtained by measuring the volume of single buildings (Fig. 2d). For risk assessments, the number of floors in combination with the footprint area provides information on floor space from which cost and loss functions can be calculated. Floor space is also useful to more precisely estimate population densities. Estimating building volume requires height and area. Area can be derived from the footprints while height is typically derived from stereo imagery.

Information extraction

Exposure maps described above are most often derived through lengthy visual analysis procedure, but advances in image processing suggest that the similar products may be produced more efficiently using advanced machine-assisted procedures. New computer based algorithms to map building footprints from single date imagery or building volume from stereo imagery are fairly advanced even if they do not produce products with the precision from visual analysis.

Advanced computer-based algorithms may produce alternative products to a building stock or land cover land use map. One such product may be a settlement map—a binary built-up / not built-up map that contains manmade structures as in an urbanized area. The simplest way of representing

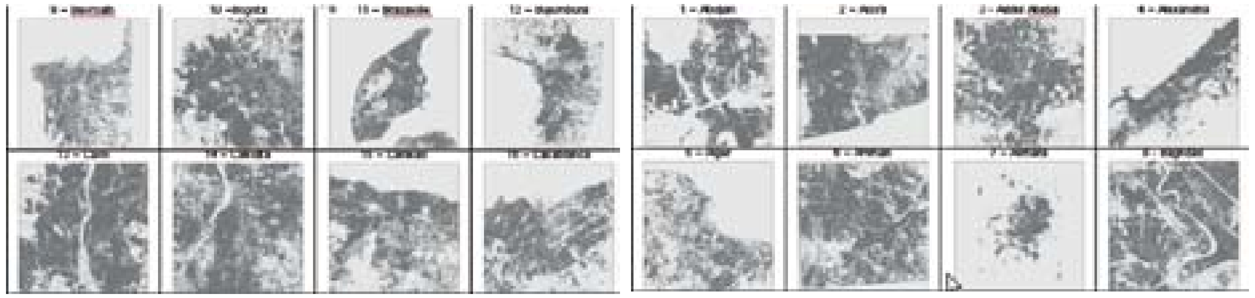


Figure 3. Example of binary built-up maps for a number of cities derived through machine-assisted procedures

A range of airborne and satellite-borne sensors provide oblique looking images that can be used to characterize the built-up or building stock.

an urbanized area is by delineating the overall settlement extent. Settlement maps can now be derived using automated computer techniques. These techniques are typically computed over larger regions such as an entire metropolitan area and, if imagery is available, over countries (Fig. 3).

State-of-the-art image processing also addresses the characterization of settlements based on information derived from the imagery. The aim is to identify built up-patterns that relate to functions and city neighborhoods. The research is particularly advanced for the identification of dense, irregularly spaced, and built-up patterns deprived of vegetation that are typically associated with informal settlements in many large cities of lower-income countries. Current research aims to link the Earth Observation derived built-up patterns to meaningful attributes to be used in disaster risk. Another potential use of automated image processing is in the generation of intermediate outputs that assist in better organizing the more labor-intensive manual analysis, for instance, through better sampling design.

Challenges

Earth Observation is an excellent tool to provide the location and size of built-up or building stock. Imagery, however, can only in part address the need of information about the quality of the built-up or building stock. Quality defines the value and the structural vulnerability and is part of exposure as is location and size. The latest imaging technologies that include oblique photography, stereo and multi-angular imagery, and RADAR, as well as mobile field imaging devices, can provide information to the finest image detail on a single building. That information has to be converted to statistically sound building type classification—a vulnerability class —that is related to its structural solidity and value. That step will have to be decided by specialists who may include civil engineers. Experienced and moderated crowdsourcing may be an option for covering large built-up areas.

At the local level, exposure datasets can be relatively rapidly generated from remote sensing that defines location and size, and field surveys should provide quality of the built-up. Satellite imagery can be acquired by image providers; the field expertise can be gathered from professionals with local expertise; and the relevant tools and procedures are often available in the open-source domain and derived from best practices. The challenge at the local level is institutional and relates to disaster risk awareness, resource availability, resource allocation, and training. Risk awareness needs to be raised in some local communities. Local decision makers need to advocate the development of exposure and—when available—should be allocated to both equip the staff with adequate equipment and train staff in the use of tools so the technology can be absorbed by the community.

The bigger challenge is the regional, national and global exposure datasets. That is in part institutional but technical as well. The high resolution satellite imagery for developing a building stock inventory is almost globally available from commercial image repository. The data processing infrastructure can be made available and processing the global VHR imagery archive is a daunting task but not unfeasible. It is the processing tools and procedures —in large part automated—that may not be sufficiently developed to produce products of adequate accuracy. Most importantly there is no openly available and agreed strategy on what structural vulnerability information to measure and how to collect such information for a global built-up or building stock map. Collecting the data may require a collaborative approach such as moderated crowdsourcing.

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Crowdsourcing Risk Assessment: Wisdom of the Crowds

Patrick Meier
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Crowdsourcing represents a promising but still largely untested approach for assessing risk. Jeff Howe coined the term crowdsourcing in 2006 and defined it as "the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call." The key words here are "undefined," "large group," and "open call."

Illustration: © Heizfrosch | Dreamstime.com

Crowdsourcing has been applied in other sectors and for multiple purposes including data crunching, translation, geolocation and transcription. While the application of crowdsourcing may be new for many sectors, the approach is a well-known and established sampling method in statistics. Crowdsourcing is just non-probability sampling. The crowdsourcing of risk assessments is simply an application of non-probability sampling.

In probability sampling, every unit in the population being sampled has a known probability (greater than zero) of being selected. This approach makes it possible to "produce unbiased estimates of population totals, by weighting sampled units according to their probability selection." Non-probability sampling, on the other hand, describes an approach in which some units of the population have no chance of being selected or where the probability of selection cannot be accurately determined. An example is convenience sampling. The main drawback of non-probability sampling techniques is that "information about the relationship between sample and population is limited, making it difficult to extrapolate from the sample to the population."

The distinction between probability sampling and non-probability sampling is important when it comes to risk assessments.

Risk is typically formulated as being the product of two factors:

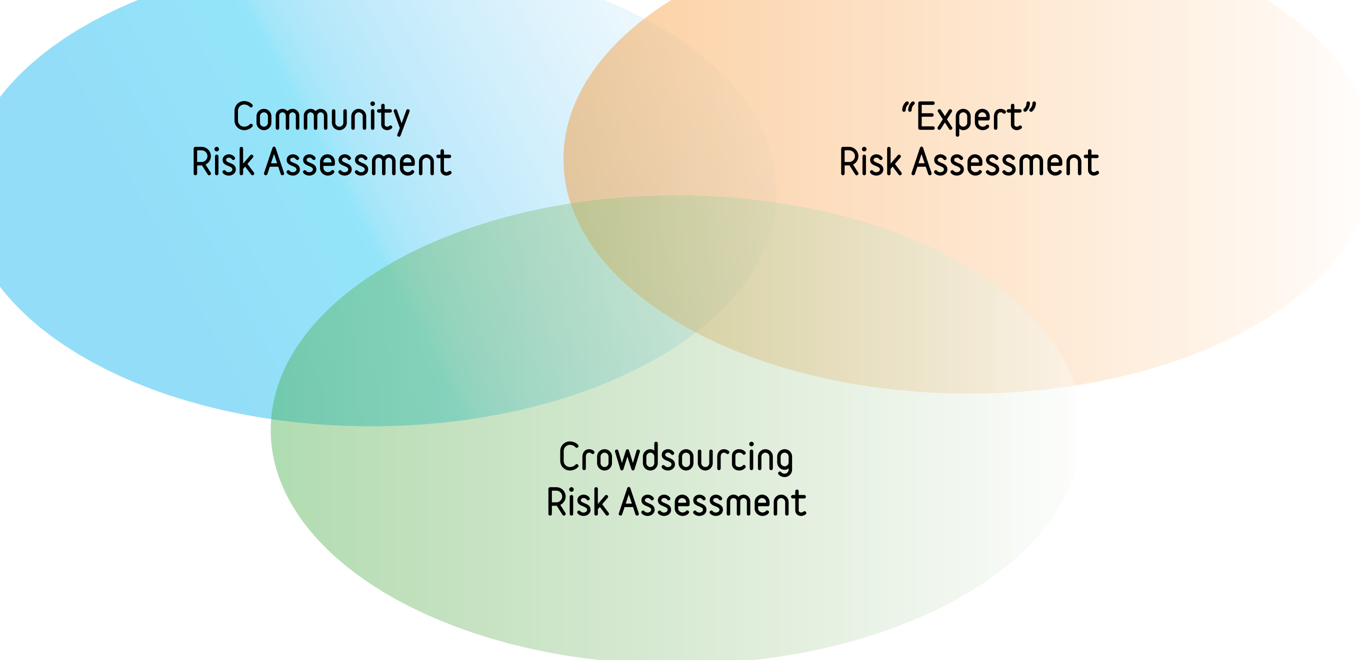
- **the probability of hazard and**
- **a given population's vulnerability to said hazard.**

The latter is necessarily a population-based figure. Herein lies the tension between traditional approaches to assessing risk and novel approaches that apply crowdsourcing. Risk is a population-based estimate that requires knowledge of population size for the purposes of probability sampling. Otherwise, these estimates run the risk of being unrepresentative of a larger population. Applying crowdsourcing—or non-probability sampling—to assess risk means that the results may not be representative.

There are several advantages to crowdsourcing, however. First, non-probability sampling is a quick way to collect and analyze data in range of settings with diverse populations. The approach is also a "cost-efficient means of greatly increasing the sample, thus enabling more frequent measurement." The method is also used in exploratory research, e.g., for hypothesis generation, especially when attempting to determine whether a problem exists or not.

In contrast, probability sampling often requires considerable time and extensive resources. Furthermore, non-response effects can easily turn any probability design into non-probability sampling if the "characteristics of non-response are not well understood" since these modify each unit's probability of being sampled. This is not to suggest that one approach is better than the other since this depends entirely on the context.

Indeed, in some cases non-probability sampling may actually be the only approach available—a common constraint in many medical studies and the recent application of crowdsourcing in Haiti. Just hours after the earthquake on Jan. 12, 2010, Ushahidi launched an interactive crisis map of Haiti and crowdsourced the collection and mapping of crisis information. A large group of volunteers from the Haitian Diaspora, the Fletcher School, Tufts University, the Geneva Institute of Graduate Studies, Lewis & Clark College, and hundreds of others around the world sifted through mainstream and social media sites to create a live map of Haiti. Just days after the launching of the Ushahidi map of Haiti, a dedicated short code was set up to crowdsource the rapid assessment of immediate needs.



Anyone in Haiti could send an SMS to the number 4636 with his or her location and most urgent need. Crowdsourcing was also used to geo-locate and translate incoming text messages from Haitian Creole into English.

According to FEMA and others, this map became the most comprehensive and up-to-date source of information on Haiti available to the humanitarian community—even though the information on the map was not necessarily representative.

That said, crowdsourcing the assessment of risk directly to the disaster-affected population itself represents an important opportunity to more quickly respond to the needs of that population. At the same time, however, crowdsourcing as an approach is not representative and also liable to false or misinformation. Note that crowdsourcing does increase the probability that information being collected can be triangulated since more information can typically be collected more quickly using crowdsourcing. In other words, the crowdsourcing of risk assessments can scale at relatively low cost while the same cannot be said of more traditional methods. This is why the crowdsourcing of risk assessments should be used in conjunction with more formal methods.

Secretary of State Hillary Clinton also applauded the initiative in a public speech ten days after the quake, noting that, “the technology community has set up interactive maps to help us identify needs and target resources....And on Monday, a seven-year-old girl and two women were pulled from the rubble of a collapsed supermarket by an American search-and-rescue team after they sent a text message calling for help.”

In sum, traditional and novel methods for risk assessments are not incompatible but can actually reinforce each other. In addition, “bounded crowdsourcing” can also be used whereby a known and trusted network of individuals source relevant information.

Suggested next steps to foster greater innovation and understanding

- The World Bank should support pilot projects that seek to apply crowdsourcing to assess risk. It is too early to organize conferences on this topic or to commission research. The use of crowdsourcing for risk assessment is in an early experimental phase and we are unlikely to learn more about the opportunities and challenges this represents without more case studies and data to analyze.
- The World Bank should catalyze the development of a “Code of Conduct for the Use of Crowdsourcing in Risk Assessments.”

Contributors to the session

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Open Source Spatial Web and Open Data

Chris Holmes
President
OpenGeo
&
Edward Pickle
Senior Vice President
OpenGeo

Building the Open Source Spatial Web and Open Data—the "Open Geospatial Web"— can help improve the identification and mitigation of global disaster risks by providing the risk assessment community with the timely geospatial information it requires. The Open Geospatial Web is key to disaster risk assessment through enabling data sharing and cooperation between all affected parties—governments, NGOs, commercial enterprises, social enterprises, and citizens. But building the Open Geospatial Web is as much a social as a technical enterprise.

Risk assessment community members build models of the probability of disasters striking, and the effects these disasters will have on people and infrastructure. But the worldwide risk assessment community (as represented by the Understanding Risk group—www.understandrisk.org) knows that even with absolutely amazing models, bad data going in equals bad results coming out. To accurately model the real world we need the Open Geospatial Web to allow access to the great amounts of data required—indeed an accurate map down to the building level throughout the entire world.

Traditionally gathering geospatial data has been a top-down affair, conducted by data experts in big institutions from governments to NGOs. If you want a risk exposure database, then you fund a team of experts to go build it. However, data now flows in many directions, and there are often many organizations that care and know about various aspects of an exposure database for their own purposes. The key is to align incentives so that all work towards the same end.

The problem of sharing data has been traditionally the domain of "Spatial Data Infrastructure" (SDI). The primary concern of SDI building has been one of reducing duplication in data gathering efforts. However, the SDI concept and framework was established before the advent of the Internet's robust social and collaborative capabilities. The amount of sharing and collaboration on the World Wide Web has begun to highlight the limitations of SDI. National and multi-national SDI programs focus almost exclusively on data from official sources, gathered in traditional survey efforts. This can have an aquarium effect—the experts swim around, outsiders admire the work, but the product remains at a distance. As a consequence, data vital to disaster risk assessment efforts are too difficult to find, or tightly held, or never shared at all.

How can we remove this "glass wall" between the top-down data gathering efforts of traditional SDI initiatives, and the bottom-up "neogeography" excitement of Google Maps mash-ups, OpenStreetMap, Ushahidi, and GeoCommons? These and other efforts have led to new and exciting forums for data creation, sharing and collaboration. How do we encourage community, sharing, and collaboration around all types of data to benefit disaster risk assessment modeling and other vital, data intensive processes?

The key is to align the incentives of everyone gathering data in an "architecture of participation", where we find ways to encourage people to participate in building geospatial information, instead of just giving them top-down mandates. "Architecture of Participation" is both *social* and *technical*, leveraging the skills and energy of users as much as possible to cooperate in building something bigger than any single person or organization could do alone. But how can we use technology to build communities that will naturally collaborate, and engage communities to build the proper technology? Participation requires both: a community will not function well if the tools to participate are too hard to use, and the technology cannot do anything if there is no supporting community.

The risk assessment community needs exposure data to complete risk calculation models. The community needs to locate the data that already exists, access and share that data, and create the data that is not in existence. It makes sense to use open data that is already available. But disaster risk assessment (and response) has a potentially even bigger role to play in the open geospatial web, as more than most any other domain it makes the need for data clear. People will readily rally around opening and creating data that will help save lives, even when such data would traditionally be locked into tightly controlled "silos."

Our panel of experts at the Understanding Risk conference in Washington, DC—including Andrew Turner of FortiusOne, Ben Wyss of the Global Earthquake Model Foundation (GEM), Ivan Lienlaf Nova of SNIT (Chile), Mark Lucas of RadiantBlue Technologies, Ole Nielsen of the Australia Indonesia Facility for Disaster Reduction (AIFDR.org), and Sebastian Benthall, GeoNode leader at OpenGeo—led a lively discussion on the role that risk assessment potentially has in building the open geospatial web.

Key ideas, requirements, themes, and action items discussed:

1. It is critical that geospatial information be as easy to find and access on the Web as "regular" information readily found with standard Internet search engines. Even the most common geospatial formats (such as shapefiles) are not as easy to find and manipulate as they should be.

2. "Open standards," "open data," and "open source" are too frequently conflated, and it is important to know the difference. Even "closed" or private data can be made readily available when open standards are employed. Software solutions based on open standards can similarly be a blend of both open source and proprietary code.

3 National SDIs work better when holdings are clearly documented and access is afforded to everyone.

4 Flexibility in system design is essential for global risk assessment initiatives like GEM —which is being established to benefit a worldwide community with hub of computing power —if the appropriate data are available. And, data and software systems need to be developed as sustainable—in order to fuel SDI data requirements.

5 Currently, GIS systems are too complex and data too unreachable. That is why unofficial data formats and tools that are easy to use, such as KML, can become official standards through their general acceptance and wide use. Ultimately, software tools and data formats that allow users to create the applications they need—like layering or "mashing up" multiple data sets into common operating pictures that anyone can develop—will be the ones that achieve wide acceptance and ultimately succeed, sometimes despite (instead of because of) government standards.

6 The open geospatial web requires both open data and open source software systems that allow users to work together and collaborate. Currently expensive proprietary software systems are the main tools available, but open source software is advancing to make collaboration capabilities more widely accessible in things like wikis for geospatial data. Software developed for collaboration has to let "basic" and "advanced" users collaborate. This software must allow the transparency and vitality of successful Internet community projects—these projects have succeeded by growing their own administrative systems and rules to allow for innovation while weeding out abuses.

7 Collaboration technology developed should allow the current serial process of geospatial data validation to become a massively parallel one. The mechanisms that social network tools allow for the building of trust networks are one example. It is critical that users be able to work together side by side. Currently even powerful and easy systems like Google Maps/Earth leave users isolated from collaborators.

8 Political and philosophical issues are as important as technological ones:

- The high level of data sharing and collaboration that was seen in Haiti after the recent earthquake was as much a function of a lack of central government delays as it was modern technology. In recent disasters in the Philippines and Chile, such a level of multi-enterprise collaboration was not possible due to government concerns and restrictions on data.
- One benchmark noted: two-thirds of system-building efforts should be in outreach and training, and only one-third in technology.
- The importance of involving ordinary people (not just technologists) in developing requirements, and including low-tech processes in systems was noted and widely discussed. This can be extended to involving other technologies, such as communications technology, in the conversation—other well-intentioned geospatial cooperation efforts have failed without such inclusion.

9 Continuing this discussion is vital.Open Source Spatial Web and Open Data at the Understanding Risk Conference was itself an analog of the effort required to build the open geospatial web to improve global disaster risk assessment—it will require strong technology development and exchange, and an even greater measure of community building and discussion.

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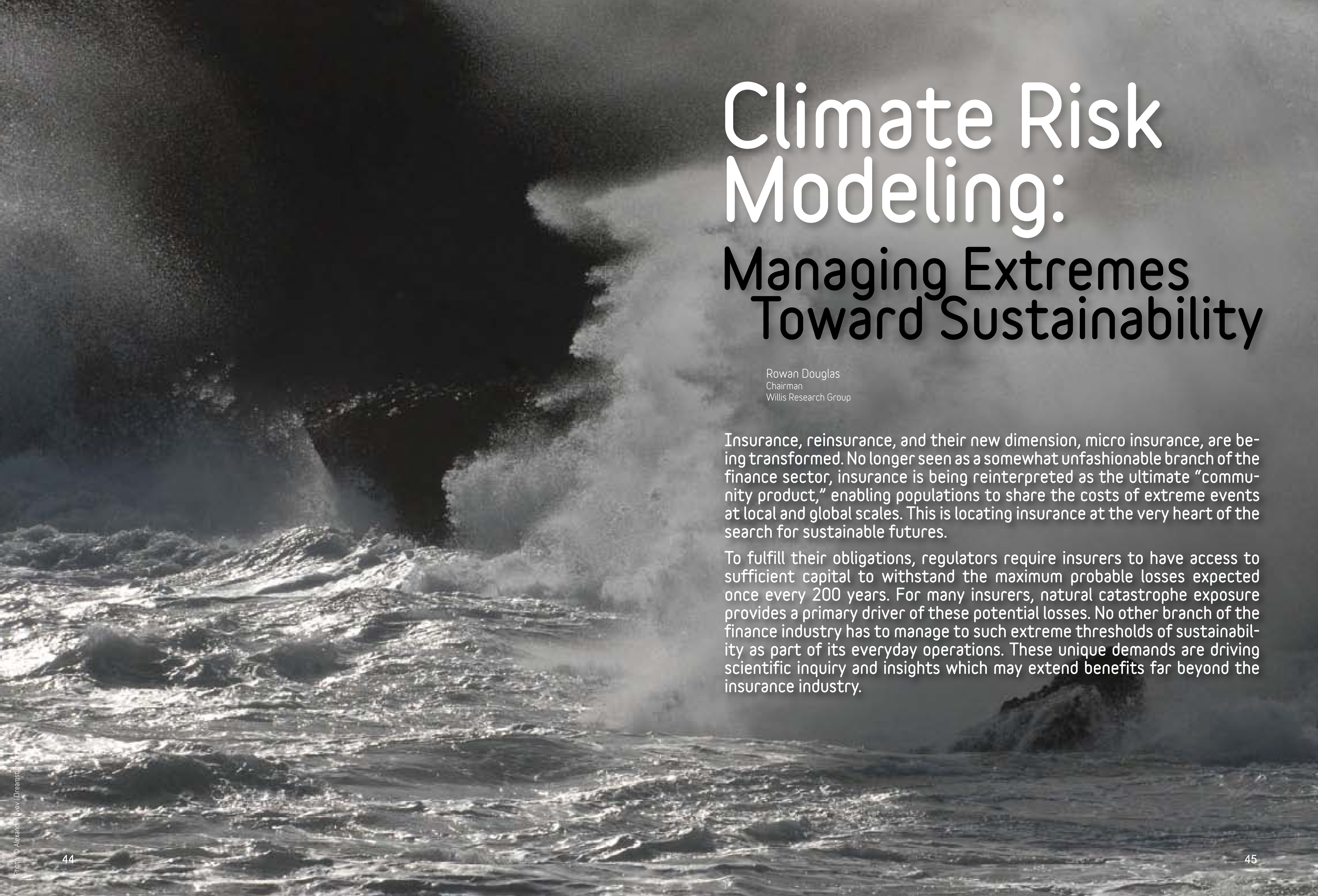

Photo: © Alexander Lvov | Dreamstime.com

Climate Risk Modeling:

Managing Extremes Toward Sustainability

Rowan Douglas
Chairman
Willis Research Group

Insurance, reinsurance, and their new dimension, micro insurance, are being transformed. No longer seen as a somewhat unfashionable branch of the finance sector, insurance is being reinterpreted as the ultimate “community product,” enabling populations to share the costs of extreme events at local and global scales. This is locating insurance at the very heart of the search for sustainable futures.

To fulfill their obligations, regulators require insurers to have access to sufficient capital to withstand the maximum probable losses expected once every 200 years. For many insurers, natural catastrophe exposure provides a primary driver of these potential losses. No other branch of the finance industry has to manage to such extreme thresholds of sustainability as part of its everyday operations. These unique demands are driving scientific inquiry and insights which may extend benefits far beyond the insurance industry.

In recent years, the insurance industry's closer collaboration with academic and public science communities, coupled with advances in high resolution climate modeling, have deepened and broadened our industry's understanding of the risks linked to extreme events.

Increasingly, the methods and principles used to evaluate and calculate the risks of natural catastrophes are being employed to understand our exposure to manmade disasters, the meltdown of financial markets, and other systemic risks. All these analyses are now being conducted in an increasingly unified "modeled world."

The Climate Modeling session at the Understanding Risk conference exemplified the growing integration of climate and economic modeling and the collaboration between insurance and public science communities.

Tom Knutson of the National Oceanic and Atmospheric Administration's (NOAA) Geophysical Fluid Dynamics Laboratory (GFDL) and James Done of the National Center for Atmospheric Research (NCAR) represented two of America's leading climate and weather modeling institutions which are actively engaged with the insurance sector to help estimate hazards and achieve a better grasp of resulting impacts, risks, and losses.

Meanwhile, Matt Huddleston of the United Kingdom Met Office, another leading climate modeling institution, illustrated how similar models can be applied to opportunities to forecast climate regimes in exposed regions months and seasons ahead.

Over the last 20 years, the insurance industry's effective integration of science has been enabled, in large measure, by specialist firms— catastrophe risk modeling companies known as "cat modelers." Pete Dailey of AIR Worldwide Corporation—one of these firms—explained how high resolution climate modeling is influencing the future direction of Catastrophe modeling and the industry it serves.

The final two speakers illustrated how these approaches are having wider impact. Howard Kunreuther of the Wharton School at the University of Pennsylvania is at the forefront of incorporating climate modeling in economic and public policy decision making around managing extreme events. Maryam Golnaraghi, Chief of Disaster Risk Reduction at the World Meteorological Organization, completed the session with further details of the WMO's framework for Climate Services and described how effective interventions to manage country risk to natural disasters would require a far greater level of integration between public, scientific, and financial communities. A growing cross-sector understanding is emerging. As part of our role in finding the most cost-effective ways to prepare for catastrophes, the insurance industry should consider its sustainability and that of its customers—be they multinational corporations or communities of farmers. The methodologies and climate modeling technologies employed by the insurance industry today to manage our exposure to extreme events also have a place in ensuring our sustainability.

In my closing remarks at the Understanding Risk conference, I invited the audience to redefine sustainability in terms of avoiding or managing extremes—from corporate financial stress and bankruptcy on Wall Street, to fighting poverty, to helping communities in developing countries mitigate and adapt to the threats posed by climate change.

In theory, financial regulation of corporate sustainability enforces better management of extremes in the same way international climate change policy supports the protection of the world's most vulnerable communities. However, as we know, theory does not always translate into practice.

The methods of risk management/transfer interventions, such as those provided by the insurance industry, can help build resilience in countries most at risk to extremes, particularly in the face of the impacts of rising global temperatures. It is estimated that economic losses from natural catastrophes as a percentage of GDP are 20 times greater in developing countries than in more advanced economies, according to the World Bank's most recent Global Facility for Disaster Reduction and Recovery (GFDRR) 2009 annual report.

Managing climate change risks requires urgent action on behalf of the insurance industry to help confront the accumulation of atmospheric greenhouse levels through reducing global emissions and to enable adaptation to changes in climate, especially from extreme weather-related hazards, to minimize harm, and maximize potential opportunities.

Without appropriate interventions and adaptation, the consequences of climate change and increased climate variability and uncertainty may lead to higher losses and associated premium increases.

For example, a Risk Management Solutions (RMS) and Lloyd's report (2007) indicated that rises in sea levels by 2030 could lead to a doubling of average annual losses from storm surge for properties in the most exposed coastal areas and around a 10-20% increase in losses that occur, on average, once in every 200 years.

Research by the Association of British Insurers (ABI) in 2005 also suggested that with a 6% increase in wind speeds, annual losses from hurricane damage to current U.S. properties would rise from around $5.5 billion to $9.5 billion, and 1-in-250-year losses from $85 billion to $150 billion. Such increases in uncertainty, expected losses, and interdependencies between climate risks as a result of climate change may have profound consequences for the future affordability and availability of coverage.

While the industrial epicenter of these issues may lie within the insurance and reinsurance industry, their nature renders them part of a wider public, economic and political discourse. The sharing of risk among populations at local and global scales, via public and private mechanisms is a subject of intense focus and debate with im plications for all of us within science and risk management communities.

Meanwhile, the increasing focus on sustainable development/growth within public policy institutions is driven partly by concerns over environment/climate change, and more recently the financial crisis. Increasingly re/insurance solutions are being viewed as a leading vehicle in response to these wider challenges in national and international society.

Summary of the current state of practice

- Simulation approach is key to understanding risk on a holistic basis.
- Simulation of real world systems have come a long way since the dawn of catastrophe modeling in the late 1980s.
- Loss validation has improved with additional, more detailed experience data.
- Better recognition and communication of uncertainty in modeling results.
- Occasional reliance on short-term history to evaluate risk and reliance on averages.

Some preliminary findings

- Lloyd's of London (2008) in conjunction with Risk Management Solutions indicated that risk from sea level rise could double the average annual losses from storm surge by 2030.
- A 2005 study by the Association of British Insurers (ABI) concluded that losses from hurricanes with a 1 in 200 chance of occurring would increase from $85 billion to $150 billion based on existing properties.
- Role of adaptation measures: Lloyd's study showed that adaptation could reduce annual losses from storm surge for properties in high-coastal communities in the 2030s to below today's levels. ($D^1 < D$).

References

Association oif British Insurers, 2005. Financial Risks of Climate Change. London: Association of British Insurers.
Lloyd's of London, 2008. Coastal Communities and Climate Change: Maintaining Future Insurability. www.lloyds.com.

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Maryam Golnaraghi, Chief of Disaster Risk Reduction Program, World Meteorological Organization (WMO)

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Risk Modeling Beyond Insurance: Analyzing the Catastrophe Exposure of the State

Stuart Miller
Senior Risk Consultant
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Governments bear significant exposure to natural catastrophes. These events can exact upon the state a range of social and economic costs. Social costs may include death, disease, homelessness, civil disorder, and the disruption of public services. Economic costs include lost economic activity, damaged infrastructure, costs of repair and reconstruction, and potential diversion of budgetary resources from other priorities.

In order to effectively manage its catastrophe risk, the state must first precisely identify what its catastrophe exposure is. Only then can a comprehensive approach to catastrophe risk management be devised to mitigate the social and economic costs of catastrophe.

The exposure of the state is in some ways similar to that of insurance companies and in other ways notably distinct. Although probabilistic models have been employed by insurance companies for over two decades, their application towards analyzing the catastrophe exposure of the state is still in its youth. As catastrophes offer continuous reminders of the state's exposure, it is worthwhile to ask whether risk modeling can be moved beyond insurance. Can risk modeling be used to analyze the catastrophe exposure of the state? If so, how can this technology be applied to the unique position of the state?

To address these questions and others, we must consider their antecedents. A starting point for discussion is—what is the catastrophe exposure of the state? When formulating a catastrophe risk management strategy, what should the state include and exclude when defining its catastrophe exposure? In particular, what is the nexus between the state and the private sector? What exposure do the state and the private sector assume the other will bear?

Hurricane Andrew is often referred to as the watershed event that brought catastrophe risk modeling into the mainstream within the insurance sector. Several prominent examples of the state applying risk modeling exist, yet the practice remains far from widespread.

What obstacles need to be overcome in order to effectively move catastrophe risk modeling beyond insurance? Is the creation of public goods a key step that will allow state to employ risk modeling to analyze its catastrophe exposure? What are the supply side and demand side constraints that hinder the use of risk modeling by the state? The focus of the conference session was to address these questions. Some of the discussion themes that emerged are summarized below.

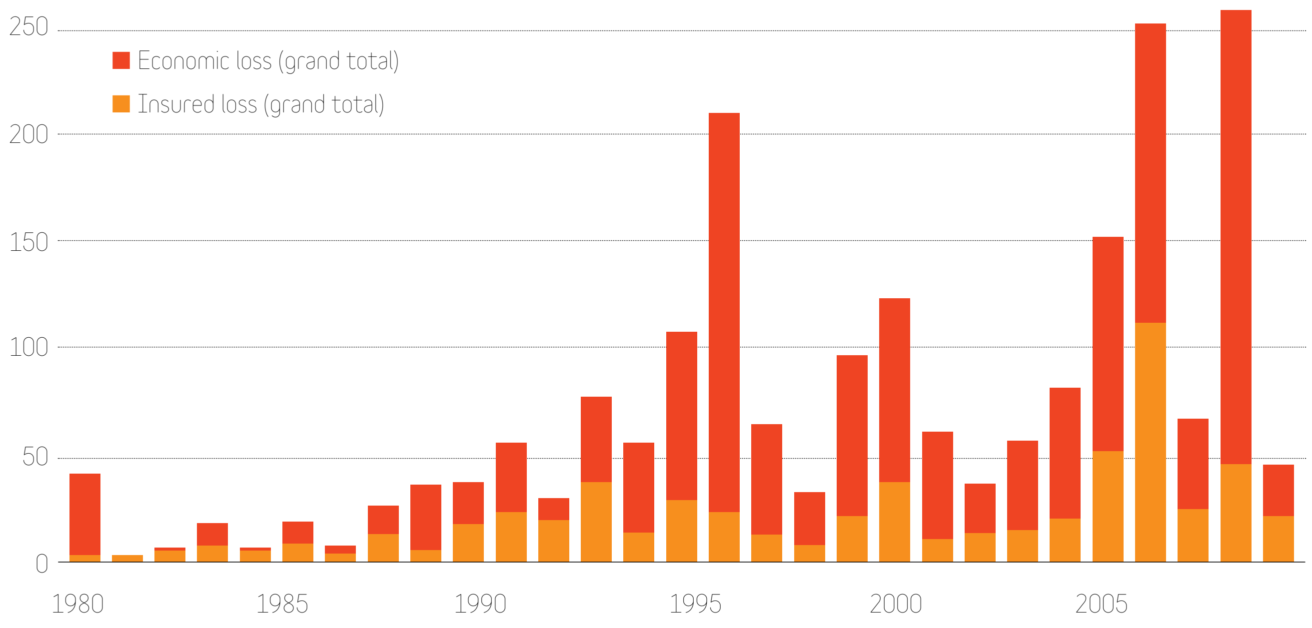
Moving risk modeling beyond insurance: exposure data

In order to move risk modeling beyond insurance, it is clear some challenges remain. One challenge is the compilation of a detailed exposure database of government assets. Although new technologies are making the collection of exposure data faster and more cost-efficient, additional information may be required to develop a robust database that can be used for catastrophe risk modeling. For example, the use of newer technologies may reduce the time to compile a database and yield precise data on the location of assets. This information is valuable, but additional data is necessary such as the construction type, occupancy, and replacement value of the structure, which may not be easily obtained from a remote collection process.

As part of its risk management efforts, Costa Rica has identified the need for an exposure database. The development of an exposure database of state assets will have important downstream benefits for more precise risk modeling results which can, in turn, facilitate risk transfer mechanisms. Evidence from Mexico underscores the value of a database of government assets. The government of Mexico has invested resources to compile a comprehensive database of public sector assets. The database contains detailed information on government assets such as schools, hospitals, roads, bridges, dams, and public sector housing. The database allows Mexico to analyze its risk profile for a variety of perils, including hurricanes, earthquakes, and floods.

Hurricane Andrew is often referred to as the watershed event that brought catastrophe risk modeling into the mainstream within the insurance sector.

Figure 1. Natural catastrophe losses in USD billions



Note: Loss amounts indexed to 2009 *Source:* Swiss Re, sigma No 2/2010

With detailed risk modeling results available, Mexico has been able to strategically purchase insurance coverage from the private sector for its portfolio of government assets.

The role of catastrophe models as public goods

Catastrophe models represent a significant investment, particularly for smaller nations which are vulnerable to a range of different hazards. Creating catastrophe models or model components that are public goods is one way of bringing the benefits of catastrophe modeling to a wider pool of users. Public goods also include risk indices such as the Disaster Risk Indicators provided by the Inter-American Development Bank. Models such as the Global Earthquake Model (GEM) and the Central America Probabilistic Risk Assessment (CAPRA) models represent such solutions. In addition to these, another interesting case study is underway in the South Pacific. The World Bank has brought together 15 South Pacific islands to participate in the Pacific Catastrophe Risk Financing Initiative (PCRFI). Under this program, the island nations will have access not only to catastrophe risk models, but also to the pooled benefits of risk financing. The World Bank worked with AIR Worldwide to create a model framework which can analyze different options for covered countries and perils. Members can explore cost-effective ways of pooling risk and securing catastrophe coverage.

Applying risk modeling for disaster risk financing

Only a fraction of global catastrophe losses are insured (Figure 1) and as populations and assets grow the potential for large losses increases. Governments absorb economic loss from emergency relief expenses, reconstruction and lost economic production, and taxes. Post-financing solutions such as donor aid, budget reallocation, and borrowing all incur risks. Pre-financing of disasters avoids these risks. For example, capital markets solutions like MultiCat do not incur debt. Country-specific approaches like those of the Inter-American Development Bank and the World Bank propose an integrated disaster risk framework which emphasizes prevention and utilizes a mix of risk transfer instruments.

Catastrophe modeling can play an important role in these efforts by assessing the fiscal impact of disasters and quantifying the contingent liability of the state. This information is useful in designing and facilitating risk transfer to the private sector. The results of the risk analyses can be credibly presented to risk transfer partners in the private sector and to ratings agencies. Using catastrophe models to facilitate catastrophe risk financing can also be a means to engage the Ministry of Finance in disaster risk management. The Ministry of Finance is usually not involved in the disaster risk management dialogue and disaster risk financing brings the Ministry into that dialogue. Catastrophe modeling can also help the government insurance regulator to better supervise the insurance industry and reduce insolvencies after a large event.

Today the application of risk modeling to governments continues to grow. In order to maximize the potential applications of modeling for sovereigns, it is important to consider the exposure of the state. A starting point is the portfolio of public sector assets, although this is by no means the limit of the state's exposure. One means of promoting the use of risk modeling is the creation of public goods, whether they are for the development of exposure databases, models or risk analytics to support risk transfer. Models can also be leveraged for disaster risk financing, which can raise the importance of risk financing and disaster risk management to government ministries not traditionally involved in these areas. In order to fully move risk modeling beyond insurance growth on the supply-side, models for new areas and new perils should be developed, and to promote growth on the demand-side sovereigns should continue to update and enhance their catastrophe risk management and risk financing strategies.

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Photo: ©Photos.com

Sub-Regional Risk Assessments: A Tool for National Investment Planning

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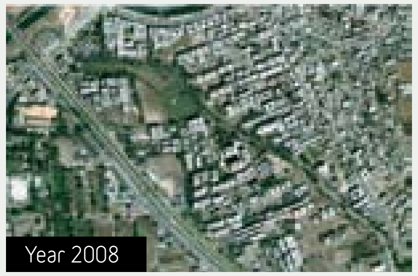
United Nations International Strategy for Disaster Reduction (UN/ISDR) Secretariat

Risk assessments offer good opportunities to create long-term sustainable investment plans that can address countries' vulnerabilities to natural hazards, but care must be taken to adjust methodologies to specific needs, and cost and timeliness are critical factors. Therefore, both detailed and quick assessments can become valuable tools when linked to advocacy and use of new technological developments in modeling and decision-making tools. Quick and basic assessments are valuable for focusing high-level political attention on disaster resilience, while detailed micro-assessments are relevant for operational decisions and designing infrastructure and land-use plans at the local level. Using risk assessments as a tool for national investment planning can help to bring together essential actors and thus ensure the much needed multi-sector participation of government institutions and academia, as well as private sector and civil society. This is important to support the formulation and application of effective disaster risk reduction (DRR) policies that are linked to sustainable development and poverty reduction.



Pune India: Increased flooding is a result of urbanization

- Storm water management is NOT JUST roadside drains...
- As urban centers grow—natural land formations are altered for building and transportation.
- "Paved" area increases multi-fold resulting in increased runoff—the increase can be up to 3 times—causing nearly 95% runoff.
- Coupled with blocked natural drainage, this increased flow causes flooding.

An online dialogue preceded the plenary session of the Understanding Risk Forum. More than 60 Governments including India, Sri Lanka, Kenya, Georgia, and Macedonia, experts and inter-governmental organizations like the African Union and World Bank, United Nations Development Program (UNDP), and others participated in the online discussion and made presentations in the plenary.

Questions raised in the online session included how to obtain fiscal commitments from economic ministries for investing in risk reduction, how to trade off between quick risk assessments versus more costly and detailed micro-risk assessment, and how to ensure cooperation across borders regarding trans-border risks like Glacial Lake Outburst Floods (GLOF).

Recent evidence from earthquakes in Haiti, Philippines, and China continues to show that in most cases countries are caught off guard when a disaster strikes. Capacity to engage and sustain political support for mainstreaming of DRR in many countries seems to be cyclical at the best, and frequently driven by the occurrence of large-scale disasters that requires a visible political response. Quantifying risk levels by identifying potential loss to Gross Domestic Product (GDP), infrastructure, and livelihoods for various future hazards at the regional, sub-regional, country, and local levels can help to maintain political momentum for reducing disaster impacts. It is important to put in place effective DRR policies that are linked to sustainable development and poverty reduction, and that government institutions and academia, as well as the private sector and civil society, participate in the development of those policies. It is equally important that well-informed decisions are made for investments in DRR.

Disaster risk assessment at regional, sub-regional, and country levels

Disasters can have enormous socio-economic consequences. The quantitative economic risk assessment performed in these studies confirms that a catastrophic event with a 200-year return period (0.5 per cent Annual Exceedance Probability (AEP) would have a major impact on developing countries' economies, which are already fragile. To gauge the potential economic impact, the Economic Vulnerability (EV) ranking of each country has been estimated in terms of likely economic losses that an event with a 200-year return period would cause as a percentage of that country's GDP. As an example, Figures 1 and 2 show the comparison of such a catastrophic event in Central Asia and Caucasus, and South Asia regions. In Central Asia (Figure 1), it can easily be seen that a

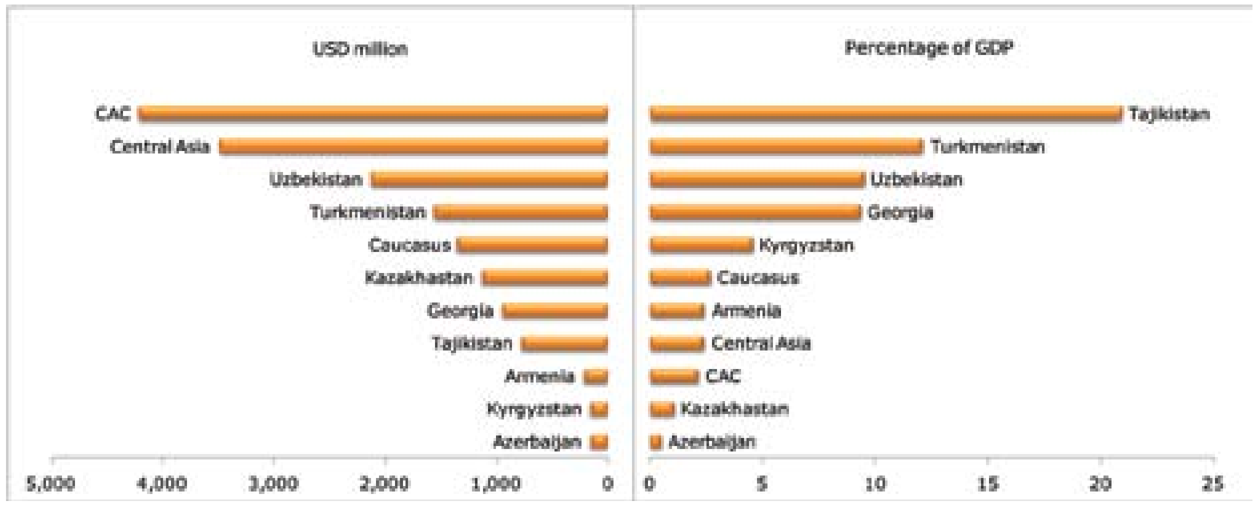


Figure 1. Loss Potential for 200 years return period (0.5 per cent AEP) in Central Asia and Caucasus

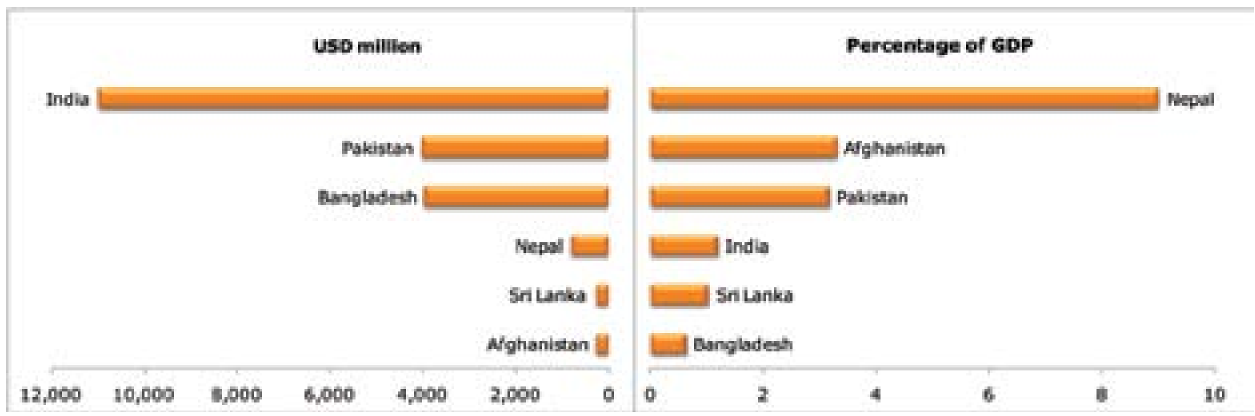


Figure 2. Loss Potential for 200-years return period (0.5 per cent AEP) in South Asia Region

catastrophic event with a 200-years return period in Tajikistan will impact country GDP by 21 per cent, while a similar event in Kyrgyzstan will impact country GDP by 4.6 per cent. Thus, it can be concluded that Tajikistan is at much higher risk than Kyrgyzstan, and such a catastrophic event will derail the country's economy and development for several decades back and aggravate poverty. A similar comparison can be made for the South Asia region (Figure 2). A catastrophic event with 200-years return period (0.5 per cent AEP) will impact India, Bangladesh, and Nepal GDP by 1.2, 6.4, and 9.0 percent, respectively.

These comparisons also prove that large developing economies, such as India are less susceptible to economic impact of disasters than small developing economies such as Nepal. Such risk assessment analyses and comparison can also help in creating a deeper awareness in countries' financing and planning ministries of the need to invest in DRR.

Recommendation to technology providers

▶ **Establish partnerships for risk analysis:** Partnerships should be established to perform three levels of analyses in order to refine the results of risk assessments. These analyses should focus first on damaging, quick onset disasters, such as earthquakes, floods, typhoons (tropical cyclonic storms), and tsunamis, as applicable.

Level 1: An analysis based only on historical records should be performed to include an accurate and robust dataset of regional disasters. .

Level 2: Worst-case scenarios should be considered for highly populated cities. This analysis would provide a reasonable quantification of loss, given the occurrence of a particular disaster scenario. The uncertainty around the risk could then be bracketed by scientifically estimating the range of probability of occurrence of such scenarios. Such worst-case scenario studies can be used in preparation of city-specific Disaster Management Plans (DMPs).

Level 3: Fully probabilistic analysis containing all the elements of standard risk analysis should be performed for the hazards and regions identified as high risk in levels 1 and 2.

Recommendations to policy makers

▶ **Promote regional cooperation:** The trans-boundary nature of some climate and extreme weather induced disasters such as GLOF in Himalayas or the Andes, earthquakes (including Tsunami), cyclone, flood, and drought, require sub-regional risk assessment with data-interoperability, so that cross-border cooperation in sharing and monitoring hazard levels and developing early warning protocols can be promoted (Figure 3). The work undertaken by the United Nations International Strategy for Disaster Reduction (UN ISDR) along with the World Bank in strengthening the capacity of regional intergovernmental organizations like the South Asian Association For Regional Cooperation (SAARC), the Association of Southeast Asian Nations (ASEAN), the Pacific Islands Applied Geoscience Commission (SOPAC) and facilitating joint regional risk assessments for identifying potential GLOFs in the Himalayas with the International Centre for Integrated Mountain Development (CIMOD) needs to be further strengthened.

▶ **Strengthen institutions:** In conjunction with greater regional cooperation, the strengthening of relevant institutions is crucial for developing strategies towards hazards of a trans-boundary nature. Decentralizing those institutions and carrying out strengthening according to a commonly accepted framework could be a way of maximizing the potential benefits of such enhancements. By considering the characteristics of the terrain and size of the countries involved, different strategies could be merged with the development planning process to work towards DRR.

▶ **Develop a centralized database:** Improving access to information could enhance the capacities of all the regional inter- governmental Disaster Centers like the SAARC Disaster Management Center (SDMC) and SOPAC countries. Some centralization and coordination of data gathering both within and between countries, particularly information relating to earthquakes (including tsunamis), and other hydro-meteorological events, could

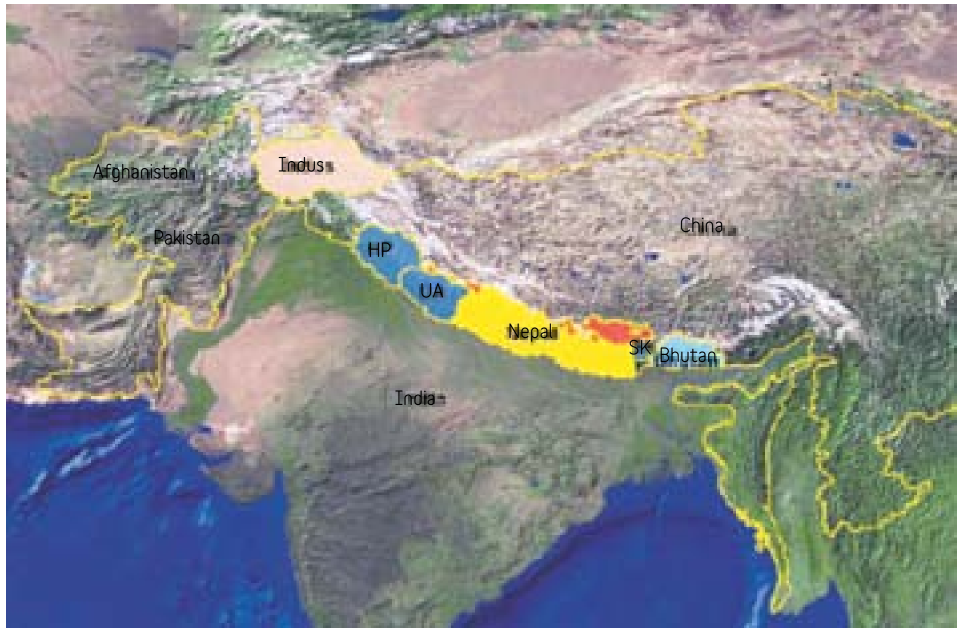
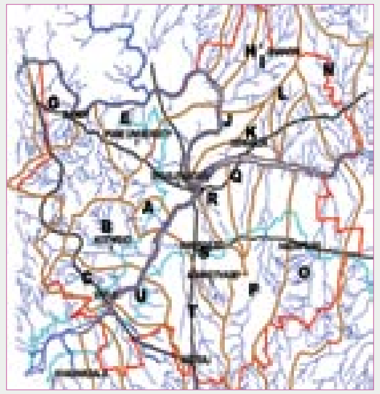


Figure 3. Location map showing regional inventory of glaciers and glacier lakes studied in Bhutan, India, Nepal, Pakistan, and China by ICIMOD along with national partners (1999–2005)



Identify watersheds

- Base map developed from satellite imagery
- Watersheds for streams that join the river were identified and marked on base map
- A total of 23 watersheds have been identified and named

facilitate data interoperability for early warning and hazard monitoring and foster regional cooperation on trans-border risks. Indeed, the presence of trans-boundary zones of high seismic activity and rivers whose flow or dam management has a direct impact on neighboring countries makes such coordination imperative. Decision-making tools, such as disaster information sharing and communication networks should be operated at all levels of disaster management – from policy making to preparedness, mitigation, and response and recovery activities. With the exception of earthquakes, the onset of major hazards such as floods can normally be predicted. Consequently, measures such as public education and early-warning mechanisms could significantly reduce the number of deaths and other losses caused by disasters. Again, trans-boundary cooperation and coordination could significantly.

Recommendation to national disaster management agencies

Improve disaster risk assessment: Although most of the vulnerable countries have DMPs in place, they could each benefit from greater refinement as the plans tend to lack the detail necessary to reflect ground realities. This could be efficiently achieved through establishing plans based on the kind of level 2 and level 3 analysis mentioned in "Recommendation to technology providers" from previous page, reflecting realistic scenarios and associated responses. In addition, the DMPs could be integrated into local development plans, which in turn could be further assimilated within regional and national programs. Carrying out disaster risk management activities within a common framework would facilitate their integration at the national level (in the form of national DMP) or trans-national level (in the form of trans-national/regional DMP).

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CAPRA

The Central America Probabilistic Risk Assessment

Measuring the Unmeasurable

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The Central America Probabilistic Risk Assessment (CAPRA) initiative provides different type of users with tools, capabilities, information, and data to evaluate disaster risk. The principles of probabilistic risk assessment are applied to the analysis of earthquake, tsunami, hurricane, volcano, floods, and landslide hazards, enabling a common language to measure and compare risk.

www.ecapra.org

CAPRA applications include a set of different software modules for the different types of hazards considered; a standard format for exposure of different components of infrastructure; a vulnerability module with a library of vulnerability curves; and an exposure, hazard, and risk mapping geographic information system. Experts and national governments have been working together towards planning for the national repositories of such data. Additional envisioned applications are cost-benefit analysis for risk mitigation alternatives, financial risk transfer and retention strategies, on-time damage estimates, land use planning scenarios, and climate change studies.

The platform's architecture has been developed to be modular, extensible, and open, enabling the possibility of harnessing various inputs and contributions. This approach enables CAPRA to become a "living instrument." CAPRA's innovation extends beyond the creation of risk modeling platforms. A community of disaster risk users is now growing from individual countries. Practical training and workshops by regional experts in disaster risk management are under development and a complete strategy for future development is under way.

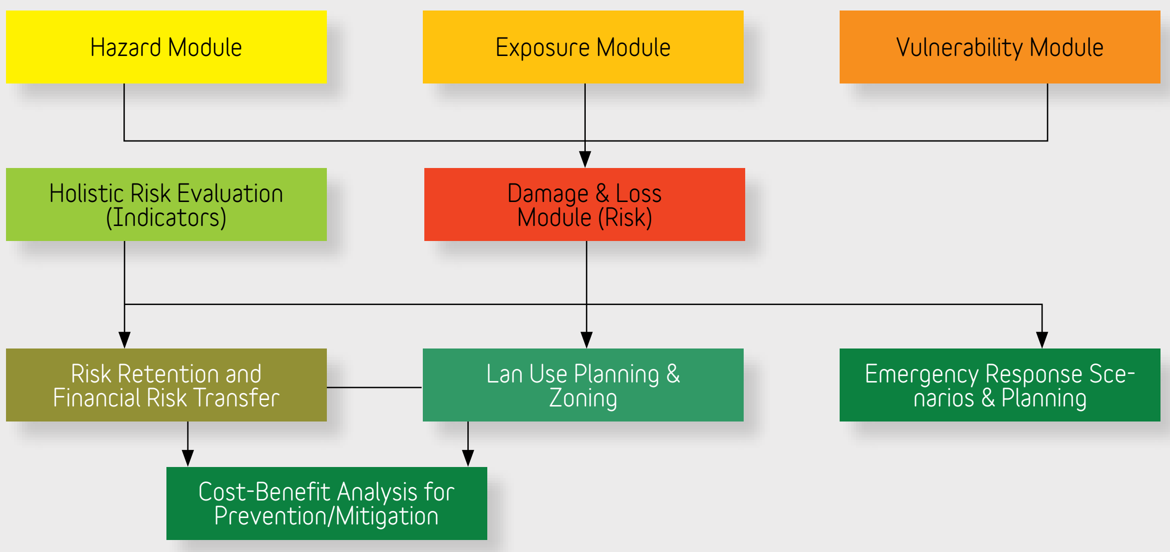
The first phase of this ambitious initiative began in Costa Rica and Nicaragua and was sponsored by the Global Facility for Disaster Reduction and Recovery (GFDRR). The second phase has already begun expanding CAPRA applications to Guatemala, Salvador, Belize, and Honduras. Subsequent phases, now ready to be launched, will see CAPRA expand in the near future to other countries in the Latin America region, while continuing to refine and grow the platform's technical capabilities.

CAPRA is now making a significant contribution to the field of disaster risk reduction and preparedness, strengthening the region's sustainable development. CAPRA will certainly be the reference risk analysis engine for the entire region in the near future. (www.ecapra.org.)

Probabilistic risk modeling

Probabilistic techniques of CAPRA employ statistical analysis of historical datasets to simulate hazard intensities and frequencies across a country's territory. This hazard information can then be combined with the data on exposure and vulnerability—of population centers or critical infrastructure, for example —and spatially analyzed to estimate the resulting potential damage. This measure can then be expressed in quantified risk metrics such as a probable maximum loss for any given return period or as an average annual loss. Since this risk is quantified according to a rigorous methodology, users have a common language for measuring, and comparing or aggregating expected losses from various hazards, even in the case of future climate risks associated with climate change scenarios.

Probabilistic risk model and disaster risk management applications



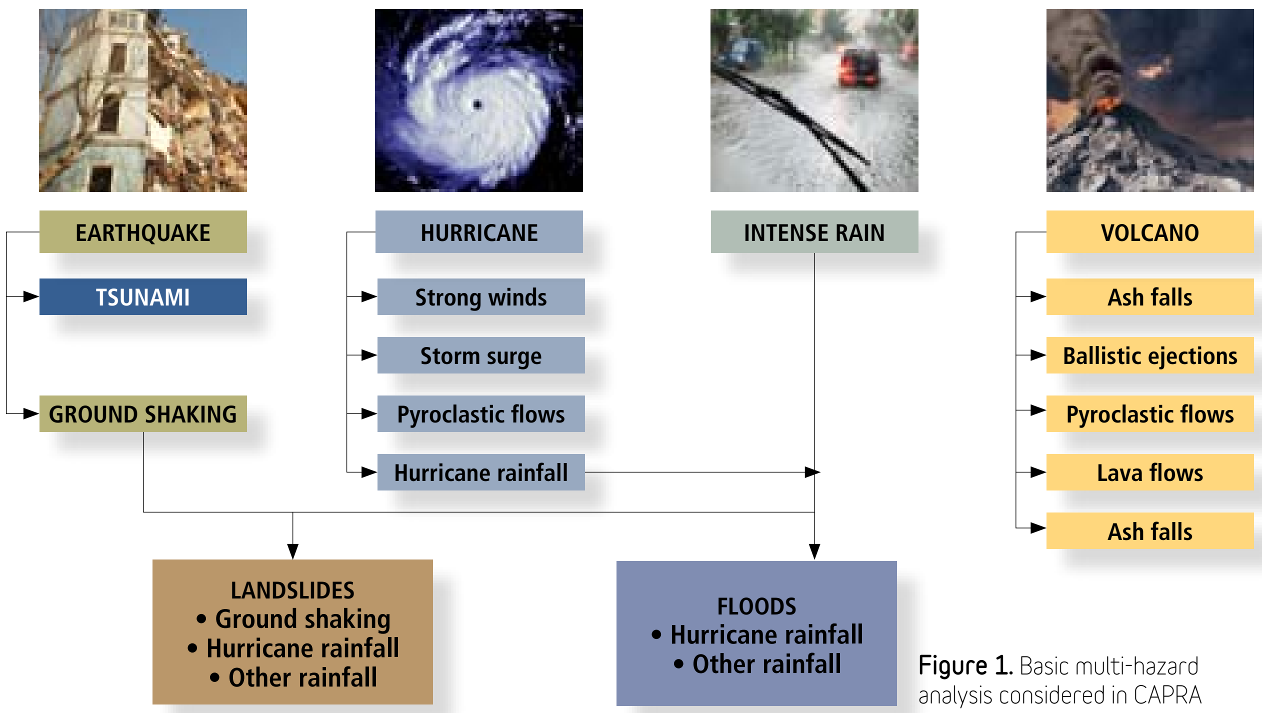


Figure 1. Basic multi-hazard analysis considered in CAPRA

Open architecture

The CAPRA initiative has been built within an open architecture platform. At the data level, CAPRA sets protocols, access, and usage rights in order to use a wider and richer source of information, which was once scattered, inaccessible or unrecorded. The architecture of CAPRA is modular, extensible, and open source, which allows it to be modified, improved, and expanded. This means experience can be accumulated rather than lost, harnessing the collective work of contributors. The contributors allow the platform to grow and adapt with each new problem creating a 'living instrument' that exists in the public domain without relying on black-box models and avoiding the problems of vendor lock-in.

Hazard modules

In the context of CAPRA, hazard is defined as a collection of stochastic scenarios, or events, that collectively define all manners in which events can take place in the region of study. Each scenario in the collection must have an annual frequency of occurrence and must describe the geographical variability of intensity during the scenario occurrence. Intensities produced during the occurrence of an event are local measures of severity. For instance, intensity during an earthquake could be measured with peak ground acceleration. However, there is the possibility that severity is not completely described with a single intensity measure. In the context of probabilistic risk analysis, intensities during a scenario are not numbers that are precisely known. Therefore, they must be regarded and treated as random variables. This implies that, in order to describe each of the intensities that are produced during a scenario, statistical moments of the random intensity must be given to define its probability distribution conditioned to the scenario occurrence.

Hazard representation is given in CAPRA by means of AME files (and AME interfaces) that contain the information described above. The hazard modules are coded with special capabilities to generate a complete set of stochastic events representing the hazard for the zone under study and to store this information in an AME file (Figure 1).

Exposure module

The exposure values of "assets at risk" are included in a standard shape format file. Information is either gathered using complementary tools, estimated from available secondary data sources such as existing databases (cadastral database or information from population census) or derived from a proxy or simplified procedures based on general macro economic and social information such as population density, construction statistics or more specific information. According to the information available, a new input data base is constructed based on GIS and specific required information is completed. Exposure information has to be specified in a shape format file (Figure 2), characterizing components either by polygons, polylines, or points. In addition, in order to calculate the impact on the population, general information related to building occupation is also estimated.

Vulnerability module

The vulnerability information quantifies the damage caused to each asset class by the intensity of a given event at a site. The development of asset classification is based on a combination of construction material, construction type (say, wall and roof combination), building usage, number of stories, and age.

Damage during an earthquake, for example, is regarded by CAPRA as an uncertain quantity and is thus treated as a random variable with Beta probability distribution. Since this distribution requires two parameters, vulnerability definition also requires two parameters: the mean damage ratio (MDR) and a measure of the uncertainty in the damage ratio, given in terms of its standard deviation. The MDR is defined as the mean ratio of the expected repair cost to the replacement cost of the structure. A vulnerability curve is defined relating the MDR and its standard deviation to the earthquake intensity, which can be expressed in terms of maximum ground acceleration, spectral acceleration, velocity, or displacement at each location.

Specific vulnerability curves can be defined for direct physical losses, for building content losses, and eventually for business interruption costs. At the present stage of development, a unique vulnerability function has to be specified, which weights the participation of direct losses, as well as indirect and content losses, or in general any additional type of loss considered. The system also allows for the use of customized vulnerability functions.

The platform's architecture has been developed to be modular, extensible, and open, enabling the possibility of harnessing various inputs and contributions. This approach enables CAPRA to become a "living instrument."

Figure 2. Exposure information specified in a shape format file

The module of Vulnerability of CAPRA allows the direct inclusion of built-in functions, the modification of existing curves, or the construction of new functions based on capacity typical curves for the building system under analysis, or on previously published information (Figure 3).

Damage and loss module

To calculate losses, the probabilistic damage ratio derived in the vulnerability module is translated into economic loss by multiplying the damage ratio by the value at risk. This is done for each asset class at each location. Losses are then aggregated as required. Risk measures produced by the model provide risk managers and decision makers with essential information required to manage future risks. The following important risk measures are provided by this module of analysis:

- Loss Exceedance Curve. LEC represents the annual frequency with which a loss of any specified monetary amount will be exceeded. This is the most important catastrophe risk measure for risk managers, since it estimates the amount of funds required to meet risk management objectives.
- Probable Maximum Loss. PML represents the loss amount for a given annual exceedance frequency, or its inverse, the return period. Depending on an organization's risk tolerance, the risk manager may decide to manage for losses up to a certain return period.
- Aggregated Average Annual Loss. AAL is the expected loss per year. Computationally, AAL is the sum of products of event expected losses and event annual occurrence probabilities for all stochastic events considered in the loss model. In probabilistic terms AAL is the mathematical expectation of the annual loss for all values at risk.
- Average Annual Loss. AAL per building. Results are given of the annual average loss for each of the values at risk described in the exposure databases. Results are given in such a way that they can be easily analyzed in CAPRA-GIS environment, or in the GIS system that the user prefers.

In addition to the probabilistic economic figures, it is also relevant for disaster management and vulnerability reduction to have the losses for specific scenarios, considering some historical events or future events. This is particularly useful for the city emergency response plan

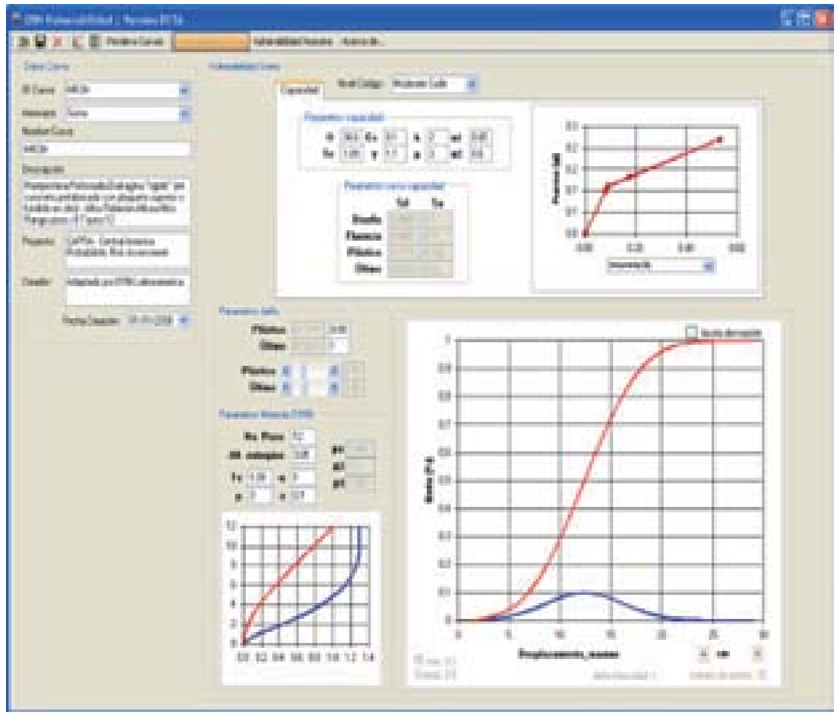
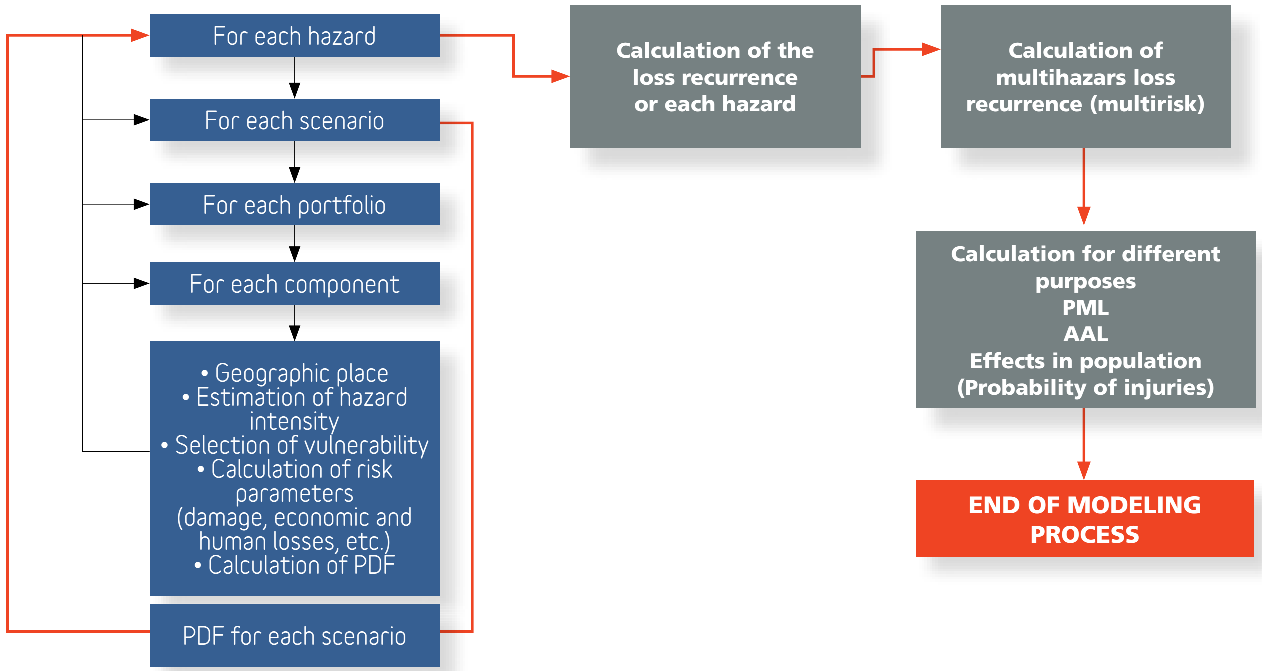


Figure 3. Vulnerability module allows built-in and a library of vulnerability curves

Figure 4. Probabilistic multi-hazard risk assessment



and to identify the buildings and blocks with potential damage concentration. CAPRA is designed to produce, upon the user's request, probabilistic loss results for specific scenarios (Figure 4).

Based on the risk results some risk communication figures have been developed and used, such as the Disaster Deficit Index used by the Inter-American Development Bank (IDB) and the Urban Disaster Risk Index (UDRI). They have been designed using the risk metrics of CAPRA to alert and invite different stakeholders to decision making. They will also be a component of CAPRA.

Next steps and future developments

The first phase of the initiative was launched in Central America with the support of the World Bank. CAPRA will be implemented on a country-by-country basis. Other potential sponsors have expanded CAPRA to other countries. The IDB is supporting the new implementations because the CAPRA objectives match the IADB's new disaster risk management policy. The basic architecture of the initiative is built through the collaboration of national governments, academic institutions, and technical experts from Central America, where existing information on hazards, exposure, and vulnerability is reviewed. Plans for the national repositories of such data are also being made. In the long run, increased participation will occur, with NGOs and community-based initiatives getting involved in the process. The launch phase is followed by a series of workshops, and ongoing capacity-building and dialogue with the countries will occur, in order to establish regional standards and inter-operability, while meeting the needs of individual countries.

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The Global Assessment Report (GAR)

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The first UN-ISDR Global Assessment Report on Disaster Risk Reduction, Risk and Poverty in a Changing Climate (GAR09) was launched by the UN Secretary General in Bahrain on May 11, 2009.

GAR09 focused on the nexus between disaster risk and poverty, in a context of global climate change. It provided compelling evidence to show that both mortality and economic loss risk from natural disasters are heavily concentrated in developing countries and that within these countries they disproportionately affect the poor. Disaster impacts have persistent, long-term negative impacts on poverty and human development, which undermine the achievement of the Millennium Development Goals (MDGs). It identified underlying risk drivers such as vulnerable rural livelihoods, poor urban governance and declining ecosystems that shape the relationship between disaster risk and poverty, and which are leading to increasing risk, even assuming a stable climate.

It also showed how climate change will magnify the uneven social and territorial distribution of risk, increasing the risks faced by the poor and further amplifying poverty.

For the purposes of the Understanding Risk Conference, and given its specific focus on innovation and knowledge on risk assessments, the session concentrated on giving attendees a broad overview of the GAR and then provided detailed presentations on the more relevant subjects of the publication as contained in Chapters 2 and 3 of the Report.

Chapter 2 features modeling of disaster risk patterns and trends at the global level, allowing a visualization of the major concentrations of risk and an identification of the geographic distribution of disaster risk across countries, trends over time and the major drivers of these patterns and trends. Given the growing influence of climate change, the centerpiece of this chapter was an analysis of the mortality and economic loss risk for weather-related hazards. In addition new insights have been gained into other hazards such as earthquakes, tsunamis, and drought.

Disaster and poverty interactions at the local level

- Evidence showed that disaster impacts have a direct and negative effect on welfare at the local and regional levels.
- Communities in poor areas lose a far higher proportion of their assets.
- Disaster impacts may lead to longer-term outcomes, particularly in the case of highly vulnerable groups such as children.
- It is clear that successive disaster impacts seriously undermine coping strategies.

Chapter 3 addresses risk patterns and poverty trends at the local level, where disaster risk reveals a complexity that is essentially invisible when observed from a global perspective, but which is critical to understanding both risk dynamics and disaster risk–poverty interactions. Chapter 3 makes use of National Disaster databases which contain impact and loss reports aggregated at the local government level of disasters of all scales.

GAR session had two main focuses

- A space in which the community could ask questions regarding the methodologies, data, process and other aspects of the GAR main report and case studies, and the presentations given during the session. Responses were provided by the Report Coordinator and two other experts who worked on the report. Most of the questions asked were requests to clarify aspects of the methodology, in particular regarding the methods to calculate vulnerability, the challenges of integrating data from multiple sources, and levels of detail, etc.
- A forum where the community discussed the findings and recommendations of the GAR and suggested new courses of action, and in general a space in which GAR authors listened to what the community had to say and suggest about further work in this area.

Feedback from participants

- The GAR is being used as a reference guide by many practitioners and decision-makers around the world, and the new edition of the GAR will be received with high expectations from many around the globe.
- The GAR, as emphasized at the Forum, is an important, innovative document on the progress of risk modeling patterns and pinpoints the challenges and issues of analysis and data on local impact when risk is viewed through a global lens. The importance of the initiatives to collect national level data was highlighted and conveyed to the community.
- The focus adopted to improve the GAR is correct: the next edition should contain more policy recommendations, on one hand, and some difficulties, challenges, and gaps in the current edition have to be addressed, i.e., better data and analysis about drought events, more coverage in terms of data and depth for Africa in general, refinements of methodologies to target Small Island States, and allowing interested parties to address national level analysis, among others, were suggested by the community. The suggestions are aligned with previous feedback and the new GAR 2011 work plan.

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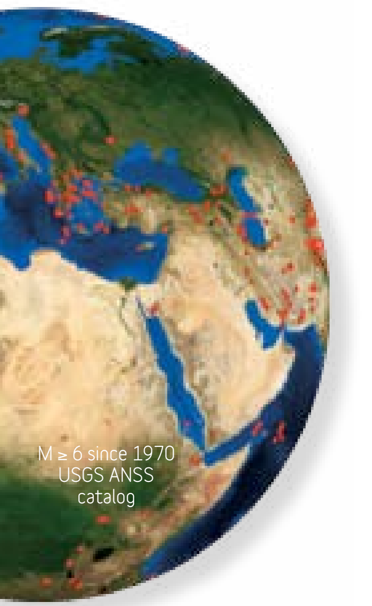
Images courtesy of R. Stein/V. Sevilgen

Global Earthquake Model

Dr. Rui Pinho
Secretary General
GEM Foundation

Almost half a million people died in the last decade due to earthquakes, and even more when one adds tsunamis (http://earthquake.usgs.gov/regional/world/world_deaths.php). Most of these casualties were felt in the developing world, where risk is increasing due to rapid population growth and urbanization (www.geohazards.no/projects/project3_08/project_3_earthq.htm - figure 2). In particular many of the world's megacities of 10 million inhabitants and more, such as Delhi, Bogota, Jakarta, and Lima, are situated in highly seismic active areas. A significant proportion of the world's population is therefore at risk from earthquakes. The 2010 Haiti and Chile earthquakes painfully reminded the world of the destructive impact of seismic events and the importance of reliable earthquake risk information. However, in many earthquake-prone regions no risk models exist, and even where models do exist, they are often inaccessible due to their proprietary nature or complex user-interface.

GEM



GEM will significantly improve earthquake risk assessment for the whole globe. GEM operates according to five-year working programs, of which the first started in 2009 and will result in the presentation of a first fully-featured version of the global earthquake model by the end of 2013. The following working program foresees extension of the model and improvement of the tools. The first version of the global earthquake model is innovative in a number of ways:

State-of-the-art

State-of-the-art information on earthquake risk (including socio-economic impact) covering all areas of the world is a necessary first step towards risk awareness and the undertaking of mitigating action. Such information is therefore a critical puzzle-piece for minimizing loss of life, property damage and social and economic disruption due to earthquakes, by leading to better buildings codes and construction, land use planning for sustainable development, improved emergency response, protection of critical infrastructures and greater access to insurance.

There is hence a need for such earthquake risk information to become accessible to a wide spectrum of end-users and beneficiaries. This need has been underlined by a call from the Organization of Economic Cooperation and Development's (OECD) Global Science Forum for the development of open-source risk assessment tools, and has been confirmed by a variety of institutions and organizations, the scientific community, and public opinion. In response to the needs outlined above, the GEM initiative will establish independent, uniform standards to calculate and communicate earthquake risk worldwide, based on a common framework: a Global Earthquake Model.

By functioning as a community effort, the GEM initiative will produce a state-of-the-art, dynamic, and updatable model for the assessment of seismic risk worldwide. The model will be based on the probabilistic assessment of earthquake occurrence, the resulting ground motions, and the impact these have on structures and populations in terms of damage and social and economic loss. It is a model with underlying databases that can be continuously improved and enlarged with future data and can be openly accessed through user-friendly software and tools for data analysis and production of results.

The global earthquake model is being designed and built by hundreds of experts and practitioners around the world. The goals are to incorporate state-of-the-art advances, ensure that less-monitored areas of our globe are also covered, and establish uniform standards that allow for risk comparisons between countries and regions, and for benchmarking output obtained through other sources. The model will reflect the needs, knowledge, and data of a variety of end-users through GEM's extensive partner-network. Such partnerships are essential in making sure that the information reaches the people that need it.

The model includes a socio-economic impact module in addition to hazard and risk (exposure, vulnerability) modules

Integration of the three modules within a common infrastructure will lead to one "model" for seismic risk assessment. (Figure 1).

Socio-Economic Impact refers to those consequences beyond direct loss and damage to people, buildings, and critical infrastructure, such as the impact on poverty, on relief and recovery needs, on long-term budgeting, on product demand, etc. Within the scope of GEM an international consortium will develop a toolbox of methods for social and economic impact analysis incorporating the needs of different types of users and are aimed at the short, medium, and long term at different scales (local, regional, and national). The international consortium, together with the wider community, will determine the most relevant methods to incorporate, for example, portfolio analysis, various types of cost-benefit analyses, but also Input-Output models or the development of national plans.

The model is being constructed by the community, and will therefore be "owned" and hence used by the majority of it

International consortia are developing databases, methods, and standards for hazard, risk, and impact assessment. Regional programs throughout the world validate these data and standards and will provide more detailed data from each region. In addition, institutions and individuals from all over the world contribute data and knowledge to the initiative. Development of the GEM IT architecture, including a computational (risk) engine, occurs from 2011 in an open source environment and involves interaction with stakeholders and end-user groups. GEM shares developments, activities, and discussions with the wider community through various communication channels and invites the community to contribute and comment.

The compilation of uniform global databases and models is unprecedented

Within GEM, seismic hazard is defined as the probability of levels of ground shaking, resulting from earthquakes, within a given time span. The hazard module of the global earthquake model is based on five components to ensure that everything relevant to hazard assessment is included. Uniform databases and catalogues on historical, instrumental and active faults /seismic source data are being compiled on a global scale for the first time; these comprise the first three components. Extending the record of large damaging earthquakes several hundred years longer and in exceptional cases by 1,000 years, but also defining methods for uniform compilation of global historical database is extremely valuable. Existing (instrumental) earthquake catalogues (1900-present) are mostly compilations of previously published ones covering different time periods and therefore they have non-uniform earthquake locations or magnitudes; within the GEM scope a uniform and updated catalogue is being produced, which honors its uncertainties and regional differences in quality and extent. GEM will produce a global database of active faults and seismic sources, as seismic hazard assessments currently do not consider faults at all, or do so only sparingly because the requisite fault data are absent or inadequate. The project will build up previous global projects, but will also cover new areas. A harmonized suite of Ground Motion Prediction Equations (GMPEs) has never before been developed on a global scale. Within GEM a group of international experts will carry out this

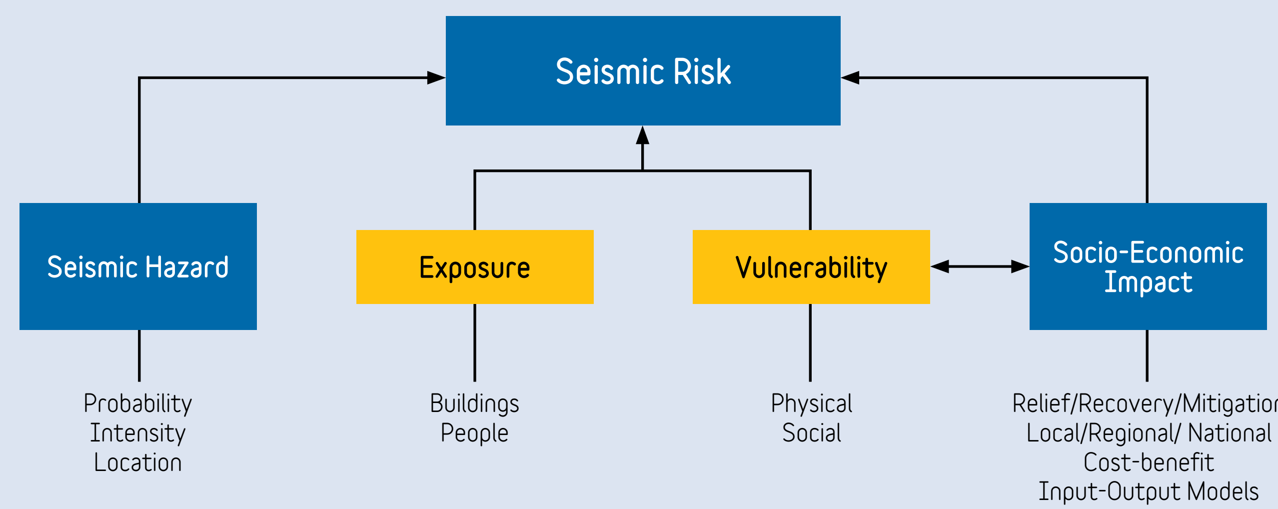


Figure 1: The conceptual model of the Global Earthquake Model

project leading to the fourth component, thereby basing themselves on the most recent advancements in the field, while interacting with all regions. The integration of a significantly improved global geodetic strain rate model is the last global component within GEM's Hazard Module. Incorporation is relevant because earthquakes release accumulated crustal strain, and hence strain rate is a proxy for earthquake potential.

Seismic risk is defined within GEM as the product of hazard, seismic vulnerability (the probability of loss given a level of ground shaking), and exposure (the elements at risk—mainly buildings, critical infrastructure, and people). The risk module of the global earthquake model also comprises five components: a GEM Ontology and Taxonomy, a Global Earthquake Consequences Database, a Global Exposure Database, Inventory Data Capture Tools, and Global Vulnerability Estimation Methods. A dedicated ontology and taxonomy will make sure that the same terminology and application of concepts is used throughout the project by all collaborators. The global consequences database will lead to uniform global data and standards for data collection on building damage, damage to lifelines and other infrastructure, ground failure (liquefaction, etc.), human casualties, social disruption, and financial and economic loss. Furthermore GEM will create the first open database of global building stock and population distribution containing the spatial, structural, and occupancy-related information necessary for damage, loss, and human casualty estimation models. The use of satellite imagery is becoming increasingly important for risk assessment and therefore tools will be developed that can capture and transfer high-resolution imagery for the exposure and consequences databases. Other tools will be developed to merge data collected from Remote Sensing with data acquired from Direct Observation. The last component within the risk module will provide global standards for vulnerability estimation (i.e., the estimation of building damage, both structural and non-structural, and associated social and economic loss) using a number of different methods (empirical, analytical, expert opinion) and a range of measures of ground-motion intensity. The international consortium working on this component will also propose default estimations, demonstrate the methods in a particular region, and propose methods for uncertainty assessment.

There is intensive cooperation on a regional scale

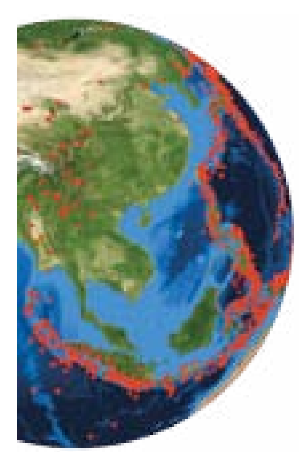
In all regions of the world GEM Regional Programs will be deployed. These are independently-run regional projects carried out under the GEM umbrella, in conformance to GEM standards and goals. Some are set up as dedicated bottom-up projects, while in other cases collaboration is sought with ongoing projects. GEM Regional Programs involve local experts who use GEM software, generate local data, validate the data and standards that are created on a global level, and serve as a starting point for workshops and trainings in the region. The various programs will complement the global datasets, especially the instrumental catalogue and seismic source database for hazard and the exposure and consequences database for risk, and contribute to refinement of methodologies and standards. Some regional programs include city scenarios and local demonstration projects.

GEM will produce open source software and user-defined tools

GEM's IT architecture is based on the latest developments in IT processes and infrastructure. OpenGEM—GEM's risk assessment software is currently being prepared for open source release. The 'engine' of the software will allow for calculations on a global level, and therefore it needs to be able to incorporate data, standards, models, and methods developed by the international community through the Global Components and Regional Programs. By building a community of developers and experts around OpenGEM development; the software, the tools and the applications built on top of it will be developed collaboratively and continuously tested. OpenGEM will be platform-independent, modular (using object-oriented language), flexible (as to allow for future multi-hazard calculations), expandable (in terms of methodologies employed), and scalable. In order to serve the needs of various users, a user-friendly interface is being constructed encompassing tools and software for transparent earthquake risk calculations and risk communication, incorporating the latest technologies for sharing data between users. This includes tools allowing continuous updates and contributions to GEM's data and models.

GEM at the community level

An active user-community and partnerships are ingredients that support initial use of the GEM tools and the subsequent promotion of the information coming out of it. An active user-community is supported by user-defined tools and a platform that allows for sharing of data and experiences. There is, however, an important role for users to act as intermediary and "translate" the information coming out of GEM for local needs. This requires good understanding of the software, and GEM will therefore deploy technology transfer methods (manuals, training modules, workshops), especially in areas where risk assessment tools and data are currently less available. Risk assessment, however, is complex, and non-experts will not be able to use the full GEM application themselves. For these beneficiaries, including those at the community level, there will be tools to support understanding of risk and where possible tools for (decision-making on) risk reduction activities. The community and the organizations representing them will be free to build complementary tools/applications where they see a need. GEM will collaborate intensively with its partner network in order to serve these beneficiaries. In close cooperation with the regions, GEM will work on local projects that demonstrate the potential of the use of GEM for (promotion of) risk reducing activities.



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Future developments

The creation of a community-owned global earthquake model is a huge effort. By 2013 the first fully-featured model and related tools and software will be presented. This model is a framework including first datasets, benchmarks, and methodologies, but these need to be complemented. For example, the exposure database of the first version will not include building aggregates, utility networks (water, waste water, energy, gas), transportation systems (road, railways, harbors), fire-fighting systems, etc. The first version will include the latest technologies and tools for data capturing, and explores technologies such as crowdsourcing, but such technologies constantly evolve and should be incorporated into the global earthquake model. Furthermore, modeling of socio-economic impact and tools to analyze it will develop at a rapid pace. There is much potential in future inclusion of methodologies and tools in the model, and also for tools to be built on top of the model that will be input for disaster risk management: decision-making, awareness raising, and risk mitigation.

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Todd Khozein Michel Matera Edgar Uribe Mary Lou Zoback Surja Sharma Rui Pinho Martin Kaufman Juliett
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Understanding Risk Team

Thank you!

What is risk?
Can we measure it?
If we understand it, can we manage it better?

The *Understanding Risk: Innovation in Disaster Risk Assessment* conference addressed these important questions. The event explored best practices in a variety of topics ranging from open source risk modeling to community-based risk assessments. New approaches in risk assessment were showcased, focusing on technological developments and the benefits of inclusive partnerships.

"An opportunity to find new partnerships that will enable us at the community level to really tap into this great world of high technology... to help communities manage their own risk"

—Daniel Kull, International Federation of Red Cross

"A rich and fecund arrangement of people ... remarkable, rich content and a clearly vital motive to be here"

—Rowan Douglas, Willis Research Institute

"A gathering of people of many different backgrounds and interests but with one common denominator: a love to understand risk and to try to provide answers"

—Jose Angel Villalobos, Instituto Nacional de Seguros, Costa Rica

"Refreshing and relevant"

—Dr. Ole Nielsen, Australia-Indonesia Facility for Disaster Reduction

UNDERSTANDING RISK

Innovation in Disaster Risk Assessment

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