

## RESEARCH CONFERENCES

ESF-COST High-Level Research Conference

### Understanding Extreme Geohazards:

### The Science of the Disaster Risk Management Cycle

Hotel Eden Roc, Sant Feliu de Guixols • Spain  
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## Highlights & Scientific Report



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# Conference Highlights

*Please provide a brief summary of the conference and its highlights in non-specialist terms (especially for highly technical subjects) for communication and publicity purposes. (ca. 400-500 words)*

Geohazards such as earthquakes, landslides, volcano eruptions, tsunamis, and floods cause large and increasing loss of lives and properties. Most of these losses occur during high-impact, extreme events. The global and long-lasting societal and economic impacts of recent extreme events illustrate the scale of disasters that can be caused by geohazards. At the same time, the recent major geohazards are dwarfed by the largest geohazards that occurred during the last few millennia. If such a mega hazard would occur today, the resulting disaster impact would be unparalleled. The potential impact on our civilization of any such rare event tends to be ignored in our planning of land use and infrastructure. Increasing global resilience and reducing the disasters induced by the occurrence of extreme hazards at an acceptable economic cost requires a solid scientific understanding of the hazards.

The conference participants from four continents and a wide range of disciplines reviewed the current understanding of high-impact geohazards and the challenges posed to the disaster risk management cycle. The presentations, panel discussions, and comments from participants showed that major research has been undertaken to understand the causes and processes of geohazards, and advances in our knowledge of the hazardous areas have been achieved. Many measures required to prepare for, and adapt to, hazards have been developed, and several international programmes are conducted informing governments, decision makers, and the general public on disaster risks, and ways to reduce these risks. Nevertheless, the loss of lives and properties through natural hazards, particularly geohazards, is rapidly increasing due to a growing population expanding into hazardous areas. The direct and indirect consequences of extreme events will likely increase as more population and infrastructure is put in harm's way and the interconnectivity of the global society increases. It was underlined that we have little options to reduce and mitigate geohazards, but that we can reduce vulnerability by properly choosing where to build and how, and by adapting existing buildings to potential hazards. The proper planning of the built environment, particularly in rapidly growing urban areas, is key to disaster risk reduction. Disaster risk reduction rarely happens in communities suffering from poverty, high levels of corruption, or opaque decision making, and adaptation to geohazards often is hampered by a biased and uninformed perception of the risks and a lack of publicly available, and easy to understand, information.

The participants agreed on a declaration identifying specific actions that would address these scientific and societal challenges. Among others, a focused interdisciplinary research effort is needed to increase our understanding of the nature of the hazards and to improve the knowledge of potential locations, intensity, and recurrence of extreme geohazards events globally. A sustained geohazard monitoring system is required to support with observations research on extreme geohazards, the detection of hazardous events, and disaster prevention, response and recovery. The importance of free data sharing in support of geohazard research and disaster risk reduction was underlined. A process for an integrated assessment of disaster risks due to geohazards and an authoritative scientific body (comparable to the IPCC) to communicate the results of the assessment were considered necessary in order to better inform decision makers. Research programmes integrating natural and social sciences need to address all phases of the disaster risk management cycle. Developing a dedicated outreach and education programme should be a priority in order to support a change in the citizens' and authorities' perception of the risks associated with major geohazards and to help recognize the challenges these hazards pose to society. Disseminating information on geohazards to relevant governmental bodies and citizens would allow for transparent decisions on where to build what and how, and where to reduce the vulnerability of existing buildings to future hazards. State-of-the-art products, actionable for policy makers are needed to support the development of legislation for risk reduction and planning for a safe built environment. Preparedness and mitigation measures need to be tailored to the specific local vulnerabilities, available resources, and social, cultural and religious constraints. Fostering international collaboration with local experts would help regions with poorly developed governance mitigate the disaster risks. Particularly in developing countries, improvements of low-technology response and rescue capabilities would ensure that disaster-impacted population could be reached more rapidly.



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# Scientific Report

## Executive Summary

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*(2 pages max)*

The conference was attended by 52 experts from four continents, many of them scientists in an early stage of their carrier. The participants included geoscientists, social scientists, economists, architects, lawyers, and insurance experts, working at universities, research institutes, governmental authorities, scientific unions, private companies, non-governmental organizations, and United Nations' agencies. The broad range of disciplines and the variety of organizations represented at the conference were key for reaching the objectives of the conference, i.e., a review of our knowledge of extreme geohazards; the identification of the scientific and societal challenges posed by high-impact geohazards for disaster risk management; the analysis of the key factors leading to increasing numbers and extent of disasters caused by geohazards, and the steps to improve disaster risk management.

After the opening session, two sessions assessed the state of the knowledge concerning location, frequency, and intensity of the geohazards, including earthquakes, volcano eruptions, landslides, and tsunamis, with a focus on knowledge gaps and uncertainties. A subsequent session addressed the question of how society can prepare for extreme hazards. Two sessions reviewed the state-of-the-art in detection and prediction of periods of increased probabilities of geohazards. Scientific methods for the collection of evidence on geohazards, new developments in the low-latency detection of hazardous events for early warning, approaches to the rapid assessment of the extent of a disaster after the event, and efforts to learn from disasters were discussed in four sessions. Two sessions discussed science support and emerging infrastructure in support of disaster reduction and considered the legal challenges for scientists engaging in societal processes of disaster management. The final session elaborated the perspective of increasing earthquake-caused disasters due to growth of exposed population, and discussed the societal aspects of this negative perspective.

The three keynotes and thirteen invited presentations provided a comprehensive overview of the scientific knowledge of the type, locations, and frequency of extreme geohazards. They also described the extent of the social and economic disasters caused by these hazards and identified the reasons for the partial failure of disaster risk management in increasing resilience to, and reducing the loss of lives and property during, disasters caused by geohazards. Fourteen contributed presentations and nine posters added details concerning our knowledge of the geodynamic processes forcing the geohazards, our ability to model and predict these processes, and the measures for disaster risk reduction. The main findings, conclusions, and necessary actions identified during the presentations and discussions are summarized in the conference declaration.

The loss of lives and property in disasters caused by geohazards is rapidly increasing. Most of the losses occur during extreme events. Extreme events are those that are outside of the usual range in terms of impact, i.e., those that cause very large losses of lives and property. These extreme events are not necessarily caused by the most extreme geohazards in terms of magnitude and energy release. Adaptation to hazards and mitigation of their impacts is insurance against future events, and a key societal challenge is the decision of how much to invest given that future events are unknown and uncertain. The basic equation for risk states that risk is the product of hazard probability times the value of the assets exposed times the vulnerability of these assets to the hazard. The economic and societal impacts of a geohazard depend to a large extent on the vulnerability of the infrastructure

and the preparedness of the impacted population. For most geohazards, we have little control of the hazards, but we can choose where and how we build, and we can choose for which of the existing buildings and infrastructure we want to reduce vulnerability. Thus, disaster risk reduction can be achieved if society has the political will and economic strength to achieve adaptation and mitigation.

In the case of earthquakes, a major conclusion expressed in a simplified way states that earthquakes do not kill people, buildings do. Buildings are “weapons of mass destruction.” The number of people killed in earthquakes and the costs of earthquake-induced disasters is increasing. However, if these quantities are normalized by population growth, the result is a steady state, which indicates that we are not learning lessons from past earthquakes. Reasons why this is so include insufficient or lacking building codes, weak or absent enforcement of building codes, corruption, and a lack of publicly available, easy to understand information on hazard probabilities and risks. The latter leads to an uninformed, biased perception of risk. In particular, legislation, regulations, and land-use planning do not have the scientific input required for informed decisions. In many developing countries, mitigation is hampered by poverty, resulting in a bias of the geographical distribution of the high-impact disasters towards developing countries: More than 80% of the deaths caused by earthquakes happen in 12% of the land surface, mostly in regions with high degree of poverty and corruption. There, too many people live and work in badly constructed buildings concentrated in exponentially expanding cities. Considering that large earthquakes in these regions kill more than 10% of the affected population, we can expect disasters with more than 1 Million fatalities. A large fraction of the deaths caused by earthquakes is due to delayed or inefficient response and rescue: in many cases, 20% of the fatalities happen during the first two hours, while most of the remaining 80% occur in the next one to three days from injuries.

Reducing vulnerability and increasing the preparedness of the population is of paramount importance. In order to achieve this, the scientific lessons learned from past events need to be used to develop forecasts and information needed by authorities, and to provide the information in a form that can be used by them. A better and open handling of the large uncertainties is a prerequisite for improved risk management. Actionable information would translate risk information into easy to understand classifications such as “negligible” and “catastrophic”, “possible” and “probable.” However, in many cases we learn lessons from recent disasters but do not apply these to the assessment of future probabilities and risks. There is also a lack of models that would allow an assessment of potential disasters due to “domino effects,” where an initial hazardous event triggers one or more natural or man-made hazards. With increasing potentially hazardous infrastructure built in areas impacted by large geohazards, such domino effects can be expected to magnify future disasters.

For earthquakes, our knowledge of the location and frequency of small to medium earthquakes, i.e. the more frequent events, is well developed, while there are significant gaps concerning the less frequent “M9” and larger events. These events are rare, and there may be far more possible locations for such events than indicated by the extreme events observed during recent centuries. A dedicated research effort is needed to improve our knowledge of the potential locations and frequency of extreme geohazards.

There are many organizations focusing on disaster risk research and disaster risk reduction related to geohazards. The building of networks bringing together individuals, institutions and organizations has to have a high priority in order to utilize the many synergies of the relevant programs.

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## Scientific Content of the Conference

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(1 page min.)

- Summary of the conference sessions focusing on the scientific highlights
- Assessment of the results and their potential impact on future research or applications

The scientific objectives of the conference were a review of the scientific understanding of extreme geohazards and to assess the scientific support for the management of the disaster risk associated with these events.

A keynote in the opening session and the presentations in the first scientific session ("*Extreme geohazards: What we know and potentially do not know*") set the stage for the conference in terms of the key scientific and societal challenges. Disaster risk mitigation is an insurance against future events, and the key societal challenge is the decision of how much to buy given that future events are unpredictable and highly uncertain. A realistic estimate of the risk and an unbiased risk perception are prerequisites for an informed decision.

Another societal and scientific challenge is to learn the lessons from the actual events that happened in the recent past, rather than to brush failures under the carpet. Governments tend to do the latter, but science also can be tardy in changing paradigms if new events require so. Unfortunately, many forecasts of extreme disasters turn out wildly wrong, not just for geohazards. An example is the Y2K case, where extreme disasters were forecasted, enormous efforts were made to mitigate the disasters, and virtually nothing happened. The answer to the question why this happens is complex: bad physics, bad assumptions, bad data, and bad luck can contribute. In the case of the 2011 Japan earthquake and tsunami, all four "Bads" came together.

Concerning earthquakes, central information for society is where, when, how big and how much shaking will happen. Errors in any of these aspects result in forecast errors. The "Where?" tends to be biased toward previous events, and thus misses future events that might occur in new locations; this is the case particularly for extreme events. What are needed to reduce this error are very long (not necessarily instrumental) records that capture the very rare events. The "When?" is again based on a too short time history and assumes that recurrence is predictable, which has to be doubted. Another problem is the choice of the area to be observed. There is a tendency to focus the location of recent events, and thus to overlook other potential areas. The "How big?" and "How much?" depends on many assumptions and can change by 200 to 300% depending on the assumptions made.

What is needed to address these problems is research to better deal with uncertainties. In particular, probabilistic hazard maps need to be tested against reality using as many of the past events as possible. Although large events are rare, the past is the key to the future. Knowledge of past events comes from instrumental data, historic records, archaeology, and geological record. Palaeoseismology is a young, multidisciplinary scientific field aiming to determine the where, when and what for earthquakes. Answers to these questions come from the analysis of high resolution Digital Elevation Models (DEMs).

Historical records also provide valuable information on location, magnitude and recurrence of large earthquake. For example, the 400-year record from Dutch colonies in Southeast Asia indicated the high probability of the 2004 Sumatra event, but this information was not acted on. Thus, the monitoring (in many forms) and research are happening, but the results are not disseminated and do not reach those who decide on mitigation. Based on the available data and research, an M9-event can be expected, for example, for the Timor Trough close to the Java coast, where a population of 300 Million would be exposed to an extreme near-field tsunami.

A scientific hypothesis previously used to exclude locations having the potential of M9 earthquakes was based on the age of the crust. The 2004 Sumatra earthquake falsified this hypothesis. However, the scientific earthquake-hazard community did not react immediately to this event (and did not apologize). Besides still relying on the hypothesis, historical records are often ignored. For example, events like the 2011 Japan earthquake were known to have happened before in the same area, but that knowledge was ignored in the land use planning and disaster risk management. It is safe to assume that a region that experienced a M9 event will not have a similar event for at least 200 years. Therefore, historical records are essential to understand the risks. Exploring the available records for the Mediterranean shows that there is a potential for a M9 in the Eastern Mediterranean. Similarly, M9 earthquakes cannot be excluded for the Caribbean Subduction Zone and the North African coast in Western Mediterranean.

For submarine landslides, characterising the frequency and magnitude of the hazard is difficult. Even for past events, the "When?" is very hard to determine with any degree of accuracy. The disaster risk for submarine landslides is associated with the potential tsunami. For coastal landslides, the warning time for the near-field impact may be too short to take action. However, for larger submarine landslides, which can cause trans-ocean tsunamis, a tsunami-warning system can significantly reduce the impact on human lives.

Sessions 2 (*"Preparing for the extreme: quantifying the probabilities and uncertainties of extreme hazards"*) and 3 (*"Preparing for the extreme: costs of preparation versus costs of disasters"*) introduced Probabilistic Seismic Hazard Analysis (PSHA) as state-of-the-art approach, designed to answer the questions "How big?", "How bad?", and "How often?" The key answer is the probability of a specified hazard level being exceeded in a given period. The result of the PSHA informs building codes, design of buildings and infrastructure, and decision-making processes. PSHA uses all viable models that are supported by data and accounts for uncertainties through models. However, consensus between different PSHAs is unlikely since no single model is "correct." The experts are often "anchored" in a model. Moreover, some experts avoid analyses in some areas due to lack of sufficient data, which has to be considered as a fallacy because one could work by analogy with other seismic zones. However, if the results of the PSHA are correct, competing social and financial interests often lead to mitigation not happening. For example, at the coast of Algeria, extreme earthquakes and tsunamis can be identified clearly in geological records. Nevertheless, new building projects, including high-rise tourist complexes, are located in the area most at risk from extreme earthquakes and tsunami.

Submarine landslides can be extreme because they can have extreme volume, high velocity, and travel far distances. Landslides are worse in shallow water, while offshore earthquakes are worse in deep water. Compared to PSHA, Probabilistic Tsunami Hazard Analysis (PTHA) is problematic to apply due to greater uncertainties associated with tsunamis. There are also problems in converting PTHA to tsunami caused by landslides due to the often local nature and a much worse database. Therefore, for landslide-induced tsunamis, it may be better to use a scenario approach. Exploration in deeper water can be expected to increase the relevance of addressing submarine landslides in coming years.

Reinsurances are important players in the economy of disasters. Their goal is to create profit from risk management. Principle characteristics of the insurances include pooling, accidental and finite loss, affordable premium, and the capital required. Extreme events from the point of view of insurance are those that need an extreme amount of capital. The market generally hardens after major events with large human, property and capital losses, and access to new capital is limited. Risk

management is based on deterministic, probabilistic and hybrid models, e.g., maximum foreseeable loss models. Most reinsurances are designed to bring science into the insurance process in order to increase resilience. Examples are the Global Earthquake Model (GEM) and hazard risk maps. Reinsurances also have an interest in realistic risk perception in society.

The comparison of recent disasters caused by earthquakes elaborates the importance of exposure and vulnerability for risk. Risk can be expressed as the product of the hazard probability times the value of the exposed assets times the vulnerability of the assets to the hazard. The disaster risk in a dense urban environment with poorly constructed buildings and infrastructure associated with a moderate earthquake is much higher than the risk in a less dense population with a well constructed built environment. Consequently, the disaster caused by the 2010 M7.1 earthquake in Haiti was catastrophic with a large number of fatalities, while the much larger 2010 M8.8 event in Chile caused less destruction and a much smaller number of fatalities. For most geohazards, we have very little control of the hazards, but we can choose where to build (exposure of assets) and how we built (vulnerability of assets). Land-use planning and building codes are therefore central elements in disaster risk reduction. Building codes are based on structural loads, which can be dead (fixed due to the building itself), dynamic (e.g., cars on a bridge) or dynamic and environmental (e.g., winds, seismic). These loads can be underestimated, and this can lead to a domino effect. Therefore, science needs to inform building codes. The perception of risk is crucial since we have to weigh the costs of mitigation against benefits.

For existing buildings, improved understanding of the risk often requires adaptation of the building. Particularly for heritage buildings, the economic impact of retrofitting can be significant, depending on building typology. A comparison of retrofit costs versus repair costs and the cost of rebuilding for different earthquakes can help to inform decisions on retrofitting.

Sessions 4 ("*Predicting increased risks for extreme hazards: earthquakes*"), 5 ("*Predicting increased risks for extreme hazards: volcanoes and landslides*"), and 6 ("*Knowing the hazards and the potential disasters*") focused on evidence of the hazards and our capability to identify and predict increased probabilities for the occurrence of hazardous events. It was emphasized again that earthquakes do not kill people, buildings do. Disasters caused by earthquakes have had a significant impact on our cultures. For example, as a consequence of the Lisbon earthquake, the European culture experienced a loss of faith after the enlightenment, and the global community experienced a loss of safety due to the recent events in Sumatra and Japan.

Science has many tools available to improve the knowledge required for risk management, including drilling, measurement of surface displacements with GNSS and InSAR, geomorphology, palaeoseismology, and, not least, modelling. Prediction of earthquakes is still a matter of research, and rather controversial. Strain accumulation determined by the ratio of interseismic slip rate to plate convergence rate helps to identify the parts of faults that are strongly coupled or locked. A combination of geodetic and palaeogeodetic methods can be used to determine the rates, while current models do not seem to capture the main phenomena.

In the Mediterranean with its densely populated and visited coastal areas, submarine landslides poses a threat to the coastal zone, as well as the submarine infrastructure related to high-density sea-floor resources. The Mediterranean has a long history of tsunamis caused by earthquakes, volcanoes, and submarine landslides. The active margins show many smaller landslides, while passive margins have fewer but larger landslides. Very little is known about the age of the landslides, and assessment of the probabilities are highly uncertain, posing a large challenge to risk

management.

Volcanoes exhibit a wide range of hazards and probabilities. A particular example is Goma in the vicinity of Mount Nyiragongo. Multiple geohazards from the volcano, earthquakes, and soil gasses, including a "killer lake," acid rain, mudflows, and landslides threaten the rapidly increasing population, which is now in excess of 1 Million people. The scale of impacts ranges from negligible to catastrophic, and the scale of probabilities from possible to probable. A number of tools, including real-time seismic and other Earth observations, are used to detect times of higher probabilities of hazardous events and to monitor the progress of these events. A range of scenarios based on past events is used to communicate the risks in schools and via radio, SMS, and conference with authorities in the Democratic Republic of Congo and Rwanda. Books and leaflets are also used to inform the population and the authorities. Key goals are to identify the hazards and understand the processes by mapping and monitoring, as a basis for making aware and preparing. Central are scenario plans, including response. Sharing of information is crucial.

Santorini is the location of one of the biggest geohazard events in human history. Large volumes of sediments originating from Santorini require a collapse of the volcano at some point in the recent history. The dating of three turbidites indicates ages of 3.6, 20 and 30-40 ka, which establishes a history of eruptions and caldera collapse. The studies of the sediments produced during these events suggests that the Minoan eruption approximately 3.6 ka ago, which destroyed a civilisation, may not have been the largest eruption.

Today, Santorini is "inflating", has hot water at subsea cones, and exhibits newly increased seismic activity. With the help of remotely operated vehicles, the cones, circular domes, cracks, and hydrothermal deposits are being studied. The Kolumbo subsea volcano to the Northeast of Santorini has active CO<sub>2</sub> vents and activity impacting the biological environment. InSAR data are consistent with these observations showing the island as a fault-controlled "flower" structure. The on-going activity warrants an integrated monitoring program.

Sessions 7 ("*Early warnings before and during the event*") and 8 ("*Assessing the disaster: the first few hours*") discussed the early warning and immediate response phase of the risk management cycle. Using the example of tsunami early warning, the warning system can be separated into an up-stream and down-stream part. Up-stream is the monitoring and detection of the hazardous event; down-stream is the creation of societal awareness, the development of preparedness, and the implementation of standard operational procedures. For the monitoring, integrated sensors are required to increase the reliability of the detection. For the propagation predictions, simulation systems are needed. Particularly for near-field propagation, detailed knowledge of the earthquake (location, depth, magnitude, rupture propagation direction) is important. Warning decisions are made based on earthquake magnitude and depth, and the detected and or predicted tsunami wave-height. Warnings are published through TV, radio, web, email, SMS, sirens. However, who gets warned depends on the view of local governments. The hazard and risk knowledge and the forecasting of the tsunami are only half of the early warning equation, the other half is the preparedness of the authorities and the population, and the response of the population to the warnings.

The expected maximum earthquake magnitude has an impact on what early warning system is necessary. Using the example of Central America, the answer to the question of whether a M9 event is possible has high relevance for preparedness and early warning. Subduction takes place below both sides of the Panama Block, from the Cocos Plate in the Southwest and the Caribbean Plate in the Northeast. Current models predict maximum events of M7.8 with small tsunamis, indicating a



minimal risk since in such an earthquake the coastline will be uplifted, with subsidence only in a small area. However, liquefaction is going to cause a problem as shaking will be strong and long lasting, and the gulf is filled with sediments from mainland rivers. However, alternative calculations indicate the possibility of a maximum event of M8.8, which would result in a much larger risk.

A promising approach to improve the low-latency estimates of earthquake magnitude and surface displacement field for tsunami propagation prediction is the use of real-time GNSS observations to determine the static offset field and to invert for earthquake rupture field. Research shows that a combination of strong motion sensors and GPS in the near field can be used for rapid inversion, providing important input for tsunami early warning systems. The 2011 Japanese earthquake provided an excellent test case because of the dense GPS network available in Japan.

Science support for responders needs to be coordinated with the responders. Scientists need to understand what responders need to know fast, which is often different from what is of scientific interest and many needs vary by regions. In the case of earthquakes, knowledge of aftershocks can be of importance to direct evacuation. However, only 3% of deaths are due to aftershocks. A rapid damage assessment identifying the area where damage is worst is crucial in order to be able to focus rescue efforts. Knowledge of the location of initial survivors is important to treat life-threatening injuries. Acceleration maps can be produced within 30 minutes, but these need to be combine with vulnerability maps to identify the locations with high probabilities of many wounded people, but vulnerability maps are often lacking or of insufficient quality. Global vulnerability mapping is still a big gap, but efforts are under way to close this gap. Frequent re-assessments of the likely numbers of wounded and fatalities also supports rescue. However, key focus should not be on response and rescue but rather on improving pre-event relationships: better preparation, more and improved education, and better communication in order to ensure that people know what to do prior and in the case of a hazardous event. The biggest challenge remains the question of how to change the fact that in many regions, buildings are weapons of mass destruction.

Sessions 10 ("*Learning from disasters: science support for recovery and preparedness*"), 11 ("*Science support for disaster reduction programs*") and 12 ("*Building infrastructure in support of disaster reduction*") discussed in more detail the link between science and disaster risk reduction. Improved methods for the characterization of risk are needed, particular since different disciplines use different definitions and no well-defined and accepted ontology is available. The problems with assessing the seismic hazards were raised earlier. The Global Seismic Hazard Assessment Project (GSHAP) made an attempt to test seismic hazard maps. It was found that all 57 earthquakes in the last decade with magnitude greater M7.5 were not consistent with the results of the PSHA. This disagreement was attributed to the PSHA analysing an area too small to account for the largest earthquakes. The Neo-Deterministic Seismic Hazard Analysis (NDSHA) using synthetic seismograms and other sources of information on seismicity could be an alternative for closing this gap.

For the sites included in the list of World Heritages, natural and man-made hazards are a particular threat since these sites often are unique. Cultural heritage can be intangible such as the traditions and behaviours in a society and the damage to a site cause by a hazard can adversely affect this part of the heritage, too. Based on the 1972 UNESCO Convention of World Heritage, states can request help with their sites, if these are in danger from natural or human hazards.

Considering disasters, scientists and other stakeholders often do learn lessons, but then these lessons are not applied to reduce the risk of future disasters. One reason may be the absence of a mandated international body to articulate the aggregated and assessed knowledge about

geohazards and the associated disaster risk. States are also reluctant to cede control and authority to an external, international body. Governments are likely to be afraid of being seen as devaluing land if they label it as being at risk. In many regions, geohazards are just one of many problems for authorities, and not the most urgent one - until disaster strikes.

The Integrated Research on Disaster Reduction (IRDR) programme aims at the transition from research to practice. A central question is why losses keep increasing despite our advances? The scope of IRDR covers geophysical and hydrometeorological disasters but not technological disasters. It considers the full socio-economics of the disasters. It is a crosscutting programme with capacity building, case studies, demo projects, scientific assessments, data collection, and monitoring. Partners include science and development agencies, research organisations, ICSU and ISSC Unions, Regional offices, UN bodies, and National IRDRs. Working Groups focus on Disaster Loss Data, Forensic Disaster Investigations, Risk Interpretation and Action, and Assessment of Integrated Research on Disaster Risk.

The 2009 L'Aquila earthquake in Italy illustrated that the relationship between scientists and governmental authorities responsible for disaster risk management can be problematic. There is no reason to assume that improved understanding of hazards and risks will easily flow through to better planning and mitigation. In the L'Aquila region, since 1990, seismic hazard maps indicated a high probability of an earthquake exceeding M5, and historical records and contemporary strain and seismicity supported this information. The high vulnerability was known. This information was provided to the government and local authorities. However, outreach was poor and preparedness and resilience were low. In the January to March 2009 period, a seismic swarm increased the monitoring and scientific outreach effort, but the lack of preparedness reduced the impact. Between March 30<sup>th</sup> and April 5<sup>th</sup>, 2009 seismicity increased and a M4.1 foreshock struck the L'Aquila area. Based on the analysis of comparable swarms, which showed that less than 1 in 100 led to destructive events, the scientific assessment was that a "major earthquake is unlikely but cannot be ruled out," which led some governmental representatives to conclude that no earthquake would happen. On April 6<sup>th</sup>, 2009 the main event happened. As a consequence, both scientists and governmental representatives are currently prosecuted. This case illustrates the need to clarify the role and responsibility of scientists in the dialog between science and those responsible for disaster risk management.

An example of infrastructure supporting disaster risk research and management is the GEM, which is motivated by an opportunity to integrate many relevant projects and to provide a common platform for an open discussion. GEM encourages participation of local experts, and a multidisciplinary approach, which involves the private sector to increase funding, to ensure relevance, and to serve many users. GEM was launched by the OECD Global Science Forum as a public-private partnership. It is implementing the open OpenQuake software development platform in combination with the OpenGEM web access. GEM stimulates projects and conducts regional workshops.

Another example is GEO and GEOSS, which address the societal benefit area of disasters. In the frame of GEO, the Geohazards Community of Practice (GHCP) has developed a Road Map detailing the steps necessary to utilize Earth observations in support of the risk management cycle. A key element are paired centres of excellence for end-to-end links between Earth observations and disaster risk management, which facilitate international cooperation with local experts in regions with low levels of risk management. GEO Work Plan Tasks also facilitate the availability of data and services for disaster risk management.

The final keynote presented concisely the results of an analysis of disasters caused by earthquakes. The average energy released by earthquakes is on the order of 80MT/year, which translates in only 2 sticks of dynamite per person per month. The number of people killed by earthquakes and the costs of the damage are increasing, but if the quantities are normalised by the growing population, the result is a steady state. This lead to the conclusion that we are not learning the lessons taught by these earthquakes. A reason for that may be that the global costs of earthquakes are with \$5 per year and person surprisingly affordable. This relatively low cost may be the reason why we are not solving the problem of disaster risk reduction. The chance of dying in an earthquake is 1 in a million, but dice are loaded: the risk is much higher or lower in some countries. Moreover, 20% of the fatalities occur in first two hours after a major earthquake, while most of the other 80% die in the next 1-3 days from injuries. The main reason for the spatial variability of the risk is the fact that too many people are concentrated in exponentially expanding cities in hazardous areas, where they live and work in badly constructed buildings. As a consequence, 84% of the deaths caused by earthquakes occur in 12% of the land surface, and most of these areas are in poor, corrupt countries. In these countries, buildings are weapons of mass destruction. The answer to this problem is education. With the rapid development of urban areas, more new houses are being built today than ever before. If we are serious about disaster risk reduction, we need to ensure that these houses are built better, and that existing buildings are retrofitted according to the hazards they are exposed to.

## Forward Look

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(1 page min.)

- *Assessment of the results*
- *Contribution to the future direction of the field – identification of issues in the 5-10 years & timeframe*
- *Identification of emerging topics*

The risk of disasters caused by high-impact geohazards is increasing, despite many research efforts in disaster risk reduction and many international programs to improve resilience and reduce these disasters. The conference succeeded in identifying the reasons for this trend, and in developing a perspective of how to address the scientific and societal obstacles that hamper significant disaster risk reduction. The scientific knowledge of the location and frequency of geohazards is most uncertain for the large, potentially high-impact, but generally rare events, and these uncertainties are poorly communicated to society and the policy and decision makers. An uninformed and biased risk perception hampers adaptation to geohazards and the mitigation of potential impacts. Importantly, significant disaster risk reduction cannot result from mitigation of the hazards, which is largely out of our control, but can only come from reduced vulnerability and exposure, and improved preparedness.

One of the main conclusions concerns the fact that the impact of geohazards will increase not because of increasing intensity or frequency of the geohazards but rather because of the rapid development of a poorly adapted built environment in hazardous areas. Today far more people and property are in harm's way, and in many cases, neither the people nor the infrastructure are prepared for the hazardous events that will happen. Particularly in many areas with poverty and corruption, cities are rapidly expanding in hazardous areas with too many people living and working in poorly constructed buildings.

Although more research on geohazards is needed, it is equally important to communicate the already available knowledge about geohazards and the reasons for the increasing disaster risk to society. There is an urgent need to alert society about the challenges geohazards pose. Dedicated outreach and education programme need to be developed for the general public and the decision makers in order to enable informed decisions in all phases of the disaster risk management cycle.

Focused interdisciplinary research is needed to better characterize the location, intensity, and

recurrence of large and extreme geohazards globally in order to assess the probability of future events. There is a need for sustained monitoring systems that provides observations needed for this research, as well as for the timely detection of hazardous events in support of early warnings, and the rapid assessment of damage after an event in support of response and recovery. In many areas, data relevant to the monitoring and understanding of geohazards is not freely shared, and an international effort needs to be made to increase data sharing.

Disaster risk reduction, which can only come from a dedication of society to reduction of vulnerability and exposure and increased preparedness, requires input from both natural and social sciences. Research programmes integrating all relevant sciences in an effort to better understand the environmental, economic and social issues in all phases of the risk management cycle are needed. Preparedness and mitigation measures need to be tailored to specific local vulnerabilities, available resources, and social, cultural and religious constraints. Actionable and state-of-the-art products need to be developed and disseminated to decision makers to support the development of legislation and the planning for a safer built environment. Fostering international collaboration with local experts in regions with high disaster risks, typically in developing countries, would help to develop there the capacity to mitigate the risks.

The Road Map of the Geohazards Community of Practice (GHCP) of the Group on Earth Observations (GEO) specifies the steps for implementing the building blocks required to better inform decision makers in all phases of the risk management cycle. The conference demonstrated that there are many organizations focusing on disaster risk research and disaster risk reduction related to geohazards, and many of these organizations were represented at the conference. The implementation of the Road Map of the GHCP will benefit from the networking with these organizations.

▪ Is there a need for a foresight-type initiative?

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The communication of the scientific knowledge concerning geohazards and the associated disaster risk to the decision makers at international, national, regional, and local governmental levels is hampered by the absence of an authoritative voice to communicate a well-vetted and widely supported message. Therefore, a process for an integrated assessment of disaster risks due to geohazards should be established. The result of the assessment should be articulated through an authoritative body comparable to the International Panel on Climate Change (IPCC). Considering the perspective of increasing disasters caused by geohazards and the potential scale of future disasters, it makes sense to consider whether such a body should be established under a United Nations' convention on disasters.

As an immediate step, a high-level community-based white paper on the scientific and societal challenges of geohazards for the resilience and sustainable development of particularly the rapidly growing urban areas, including megacities in hazardous regions, should be prepared and distributed to scientific funding agencies as well as governments and intergovernmental organizations.

## **Atmosphere and Infrastructure**

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▪ *The reaction of the participants to the location and the organization, including networking, and any other relevant comments*

The general reaction of the Conference participants to the location, organization and contents of the conference was very positive. A significant fraction of the participants have expressed that the conference was among the best conferences they attended so far. Positive comments on the venue, the meeting facilities, the high level of the invited speakers, the quality of the presentations, and the engaging discussions were frequent. The conference co-chairs have received an unusual large number of such positive comments.

The professional support of the COST/ESF staff was emphasized and commented. The social programme (welcome reception, excursion, and workshop dinner with cultural event) was well received. The fact that the

conference participants spent the full day from breakfast to after-dinner gatherings at the conference venue was very positive for a continuation of the discussions outside the main conference programme.

The conference brought together representatives of organizations in several disciplines, and it can be expected that a number of cross-discipline networking took place. Most of the participants who formerly were not actively involved in the Geohazards Community of Practice (GHCP) of the Group on Earth Observations requested to be on the mailing list of the GHCP. A follow-on meeting is already in planning for April 2012 co-located with a major science conference (European Geosciences Union, Vienna, Austria).

Already the opening session with welcoming notes from ESF, COST, UNESCO, GEO, ICSU, and IGCP Project 585 showed that there are many organizations focusing on disaster risk research and disaster risk reduction related to geohazards. The participants agreed that the building of networks bringing together individuals, institutions and organizations has to have a high priority in order to utilize the many synergies of the relevant projects and programs. During the conference, many participants used the coffee and lunch breaks, as well as the joint dinners for discussions of how such networking could be facilitated.

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N/A

## Date & Author:

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January 14, 2012, Hans-Peter Plag, Stuart Marsh