TRANSPARENT GLOBAL EARTHQUAKE RISK AND LOSS ESTIMATION

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Abstract

Global Earthquake Model (GEM) is a unique collaborative effort that will provide organizations and engineers with tools and resources for transparent assessment of earthquake risk anywhere in the world. By pooling data, knowledge and people, GEM acts as an international forum for collaboration and exchange, and leverages the knowledge of leading experts for the benefit of society. When GEM's OpenQuake platform and tools are released, the engineering community will be able to calculate earthquake risk to a common standard worldwide. By participating in GEM development, the community can contribute to making the tools ever-more valuable for loss assessment of their (local) projects.

Introduction

This paper presents an overview of the Global Earthquake Model (GEM) with particular emphasis on how GEM will integrate with the earthquake engineering community worldwide.

Motivation

Vulnerability to earthquakes is increasing, yet advanced, reliable risk assessment tools and data, a critical basis for managing that risk, are inaccessible to most. Even where earthquake risk information is available, it often lacks clear communication for practical applicability. Also, there is a lack of global standards to compare risk between locations. Sharing of data and risk information, best practices, and approaches across the globe is key to assessing risk more effectively.

Structured for Collaboration

GEM combines the strengths of the public and private sector in a continuously expanding partnership, deliberately structured to promote collaboration across sectors.

GEM is organized loosely in five main categories of participants:

- The *GEM Secretariat*, located in Pavia, Italy, coordinates across GEM activities worldwide. The Model Facility within the Secretariat implements GEM tools and software, including GEM's main software platform, OpenQuake (described further below).
- The *Scientific Community* engages by means of global projects, carried out by international consortia featuring renowned experts and organisations that develop global datasets and methodologies in the domains of hazard, exposure, physical (building) vulnerability, and socio-economic resilience.
- *Regional Initiatives* work on data collection, create regional input models, provide feedback on global projects and connect GEM data and output for implementation and capacity-building in regional and local contexts.

    - GEM's open-source modeling software - OpenQuake Engine - is being used in the nearly completed SHARE[1] project aimed to produce harmonized hazard maps for Europe
    - GEM recently hosted a workshop to share best practices in calculating and communicating seismic hazard in sub-saharan African nations.
- *Sponsors*, further comprised of public/national agencies and private organizations, provide guidance by way of seats on the GEM Governing Board.
- The *Broader Community*, including the engineering community and other potential users of GEM products, currently participate in GEM by:
    - sharing knowledge and best practices,
    - contributing data such as building typology and inventory,
    - test tools as they become available
    - provide feedback, and
    - follow GEM progress

From 2014 onwards, all these groups and many more stakeholders will additionally become users of the OpenQuake Platform and GEM products, working together toward collaborative enhancement.

Working Together to Assess Risk

GEM's first working programme (2009-2014) focuses on building a global framework; a basis that can then drive further development from global to local. This is envisaged as follows:

> *Global:* GEM groups are developing tools and standardised methods for obtaining and analysing data, and these are being used to begin the process of assembling the needed (global, uniform) datasets. The result is advanced data coverage for the world which is much more uniform and complete than before.
>
> *Regional:* At the same time, through regional, national and local collaboration, the global datasets are scrutinized, data, models and knowledge are being integrated to make the platform and tools ever more useful for application at local scales.
>
> *Organisations/Individuals:* From the end of 2014, stakeholders across the globe will be able to access state-of-the-art, widely accepted datasets, models and (open-source) software tools through GEM's risk assessment platform (OpenQuake), allowing them not only to perform hazard and risk analyses, but also to make decisions on retrofitting and insurance and collaborate and exchange data, results and opinions amongst each other.

OpenQuake is being built in a dynamic and flexible way, so that it can capture the world's best understanding of data, the earth and earthquake behaviour, and the built environment at any given moment in the future. The user community that will hence grow around the platform will enrich and continuously enhance the datasets, tools and methodologies, for transparent and more effective hazard and risk assessment, from global to local. GEM will actively support that community through training, dedicated resources and outreach, facilitating true global collaboration as basis for transparent and effective risk management.

[1] Seismic Hazard Harmonization in Europe (http://www.share-eu.org/)

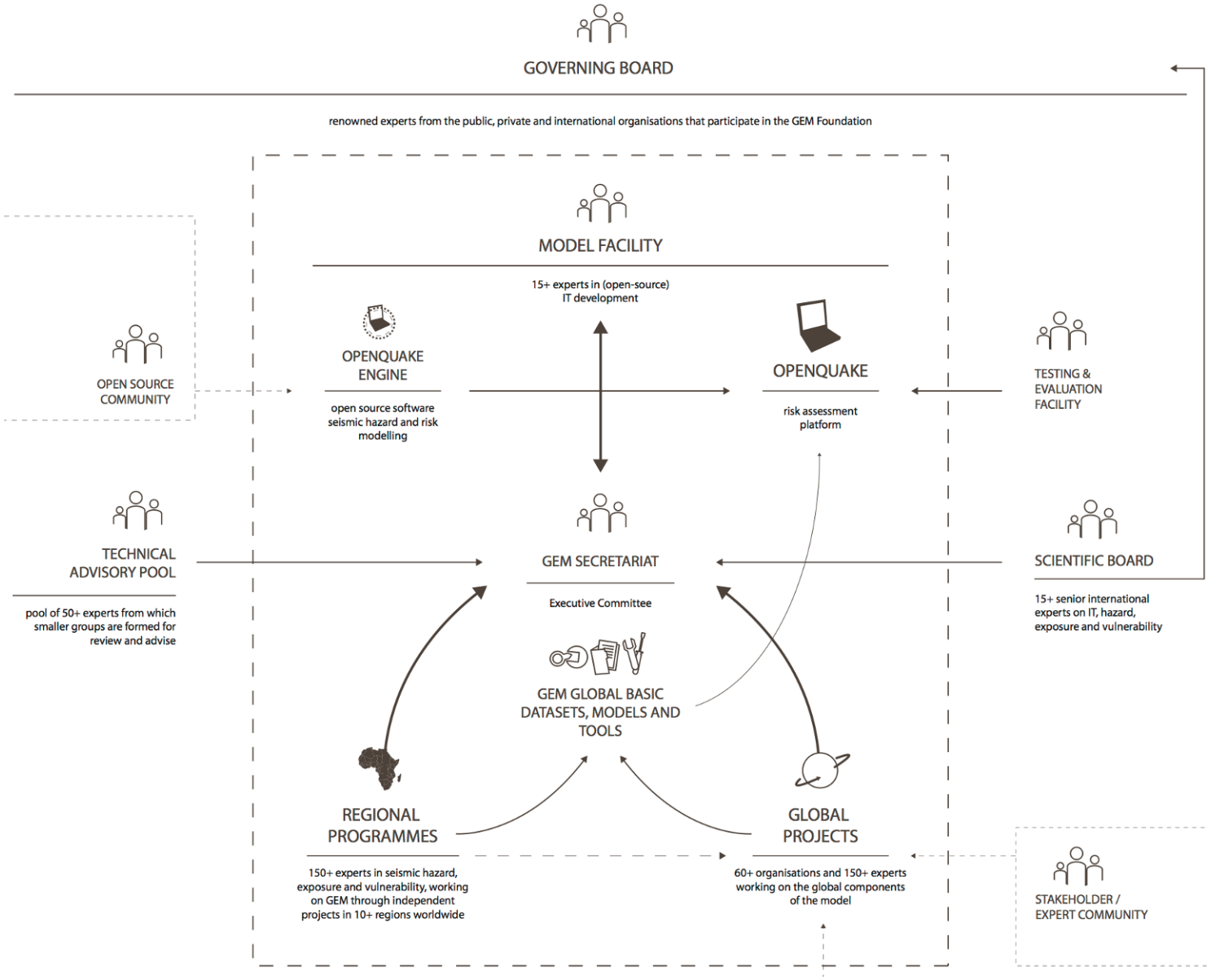

Figure 1. Collaboration among GEM Participants

Limitations. GEM's first programme will not incorporate all possible data available, nor cover all countries in the world in a uniform way. Limitations include secondary hazards such as tsunamis and landslides, as well as integration of infrastructure as part of exposure modeling. These exclusions are envisaged for future versions.

GEM Products

Building on collective efforts and knowledge of scientists worldwide, GEM will hence for the first time integrate state-of-the-art data, models, results and open-source tools into a single platform that is to serve as a clearing house for earthquake risk information.

Global Components. The global data, models and methodologies that serve as input to GEM risk assessment derives from contracted projects in the domains of hazard, exposure, physical (building) vulnerability, and social resilience:

Models:

- Seismic Source Models
- Ground Motion (Attenuation) Models
- Physical Exposure Models
- Physical Vulnerability Models
- Composite Index Models (social vulnerability, resilience, indirect loss)

Datasets:

- Global Earthquake History Catalogue
- Global Instrumental Catalogue
- Global Geodetic Strain Rates
- Global Active Fault Database
- Tectonic Regionalisation
- Buildings and Population Databases
- Earthquake Consequences Databases
- Physical Vulnerability Databases
- Socio-Economic Vulnerability and Resilience Indicators

OpenQuake. An integrated and holistic approach to risk is key to GEM's platform, OpenQuake, which has three main functions:

- ***Calculate*** The OpenQuake platform integrates open-source applications with homogenized data and models, allowing users to model seismic hazard and risk transparently and according to the latest science. From ground motion fields to hazard spectra to maps of estimated human loss and mean economic loss; users will be able to produce a great variety of custom outputs by combining own data and (local) knowledge with GEM products. A simulation engine (the OpenQuake Engine) is the core of calculating risk metrics.

- ***Explore and Decide*** The platform leverages upon open-source geospatial technologies to allow users to work in an intuitive GIS-environment. Users can explore earthquake hazard and risk by interacting with dynamic maps, indicators and graphs, develop their own maps, but also capture and integrate new data. To help users understand risk better and to facilitate risk management, decision support tools are integral to the platform.

- ***Share*** Sharing of data and risk information, best practice and approaches is key to assessing risk better. The platform is to serve as a clearinghouse for all those critical in- and outputs. It will link users from around the globe so they can work together to assess risk.

With OpenQuake, homogenized information on hazard can be combined with data on exposure (buildings, population) and their vulnerability, for loss assessment around the globe. For a true integrated view on the probability of loss and the costs and benefits of different risk management measures, users can add socio-economic information to maps and estimates of 'physical' risk.

Built for Decisions. Functionality being built into the OpenQuake platform is designed specifically for direct applicability to risk-reducing decisions. Pre-computed results will include:

- *Hazard Maps*: For example, GEM has already been used to produce a hazard map for the nation of Ecuador, for which no prior nationwide hazard map had existed.
- *Hazard Curves*: probabilistic hazard for a specific site, used to estimate probabilities of shaking
- *Stochastic Event Sets*: Full suites of hypothetical earthquakes that could affect a given region
- *Risk Maps*: Both probabilistic and scenario-based. For example, distribution of damage severity; distribution of monetary losses; distribution of deaths;
- *Event Losses*: Scenario estimates of damage, monetary loss, or social factors, whether for single sites or groups of sites, or entire regions
- *Loss Metrics*: Including average annual losses, and losses related to a specific probabilities of exceedance, both total and insured, whether for a single site or correlated for a portfolio
- *Retrofit Cost-Benefit Calculator*: Based on losses with and without improved seismic resistance
- *Uniform Hazard Spectra*: For engineering design of buildings to a consistent basis

Real-World Application

The design of GEM functionality is based on several primary anticipated users with associated use cases. As an example, as an associate partner of GEM, the California Seismic Safety Commission (CSSC) is investigating potential opportunities to collaborate with GEM and use OpenQuake tools to generate transparent risk information and economic loss estimation for California.

GEM tools will have applicability related to science and engineering, insurance and risk transfer, and particularly policy making, such as land use planning and building code enforcement.

Integration of GEM with the Engineering Community

When the GEM platform and tools are released (late 2014), the engineering community will have open access to GEM tools for calculating earthquake risk to a common standard worldwide. Use of GEM for commercial purposes will be subject to license fees, on a sliding scale based on annual revenues of the organization.

By participating now in GEM development, the community can contribute to making the tools ever-more valuable for loss assessment of their (local) projects. Participation consists of sharing knowledge and best practices, contributing data such as building typology and inventory, testing tools as they become available and providing feedback, and following GEM progress.

Figure 2: Exploring Building Vulnerability and Exposure around the globe with OpenQuake

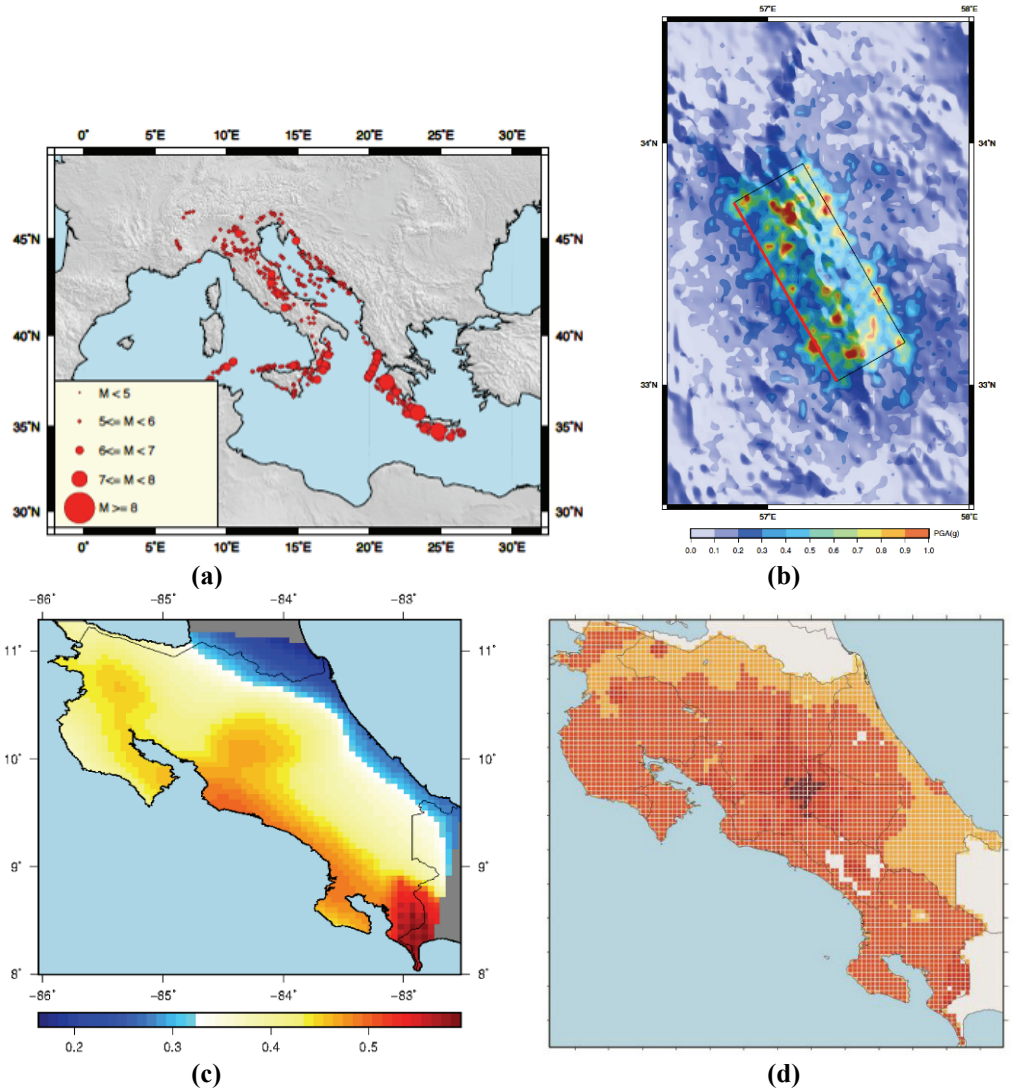

Figure 3: Various typical outputs of the OpenQuake engine (a) a stochastic event set, (b) a ground-motion field with spatial correlation of ground-motion residuals, (c) a seismic hazard map with 10% probability of exceedance in 50 years, (d) a loss map in terms of fatalities with 10% probability of exceedance in 50 years

Summary

Building on many ongoing efforts and the knowledge of scientists worldwide, GEM will for the first time integrate state-of-the-art data, models, results and open-source tools into a single platform that is to serve as a clearing house. By participating in the effort, the engineering community, and in particular private sector representatives, can leverage the platform and its tools and contribute to making them ever-more valuable for loss assessment of their (local) projects.

References

Pinho, R. (2012). "GEM: a Participatory Framework for Open, State-of-the-Art Models and Tools for Earthquake Risk Assessment". *Proceedings of the 15th World Conference on Earthquake Engineering*, Lisbon, Portugal, paper n. 4929.