Real-Time Earthquake Loss Alerts

Once an earthquake has occurred, it is vital to provide adequate and timely help. Quantitative real-time earthquake loss alerts worldwide are issued only by the US Geological Survey and the International Centre for Earth Simulation (ICES) in collaboration with the Swiss Seismological Service (SED). These alerts serve to allow authorities to mount an appropriate rescue effort and guide first responders to the most affected settlements. Based on this experience over the last 11 years, estimates of the losses in future unavoidable earthquakes are possible.

Since October 2002, I have distributed 831 earthquake loss alerts within 31 minutes (median) of the occurrence time of potentially damaging earthquakes worldwide, in collaboration with the SED (Wyss, 2014). The SED has designed a worldwide filter with cutoff magnitudes, M, and hypocentral depths to select events that should be analyzed. In Europe, the cutoff is M5.5, in other parts of the world it is 6.0, and larger in the oceans. When such an earthquake occurs, SED sends me an SMS, I drop everything I am doing, including sleeping, and calculate how many fatalities and injured may have resulted. This information is distributed by email, including maps of damage, to subscribers of the free service, and also by twitter in shorthand format.

The need for rapid estimates of losses arises because the extent of the disaster is often not known for several days. News reports of numbers of fatalities are always too low at the beginning because information flows only from the edges, not from the center, of the devastated region.

The Loss Estimating Program QLARM

From 2007 to 2009, we assembled the second generation program and data set to calculate earthquake losses, QLARM, at the World Agency for Planetary Monitoring and Earthquake Risk Reduction in collaboration with the SED, supported by DEZA. The input for the calculations consists of the hypocenter location and magnitude of the earthquake and a choice of an appropriate function for the attenuation of seismic waves. The strong ground motion expected at the settlements in the region is calculated in a first step. Next, the probable damage to each building type is derived and an index of mean damage is estimated for each settlement. A map showing the mean damage grade (Figure 1) forms a key part of the alerts distributed by email.

The impact by collapsing and damaged buildings on the population is estimated, using a casualty matrix. This is a table that gives the probability that an occupant is killed, injured, or escapes unharmed. Based on the population expected indoors, the number of fatalities and injured is calculated for each settlement. The sum of the fatalities and injured expected forms the most important part of the loss alerts.

The Data Sets

The data on population in QLARM are probably the most complete worldwide set, including approximately two million settlements and covering all countries. An example of the density of settlements contained in QLARM is seen in Figure 1, where 17,056 settlements are displayed within the 400 km radius selected for the calculation.

Modeling small settlements as located on one coordinate point is adequate. However, for large cities we have only 75 cases in which population and building stock in different districts are known separately.

The reliability of population data varies greatly from highly accurate census data to approximations pieced together from several sources on the Internet. For first responders, it is important that the losses are given for population centers by name and not by pixel with coordinates.

For some countries, the building stock data are available from the World Housing Encyclopedia, for others census data contain information and for still others photographs from Google Earth are the sole source. For those countries where large damaging earthquakes have occurred, we have updated the resistance classification of buildings according to the damage that has been observed.

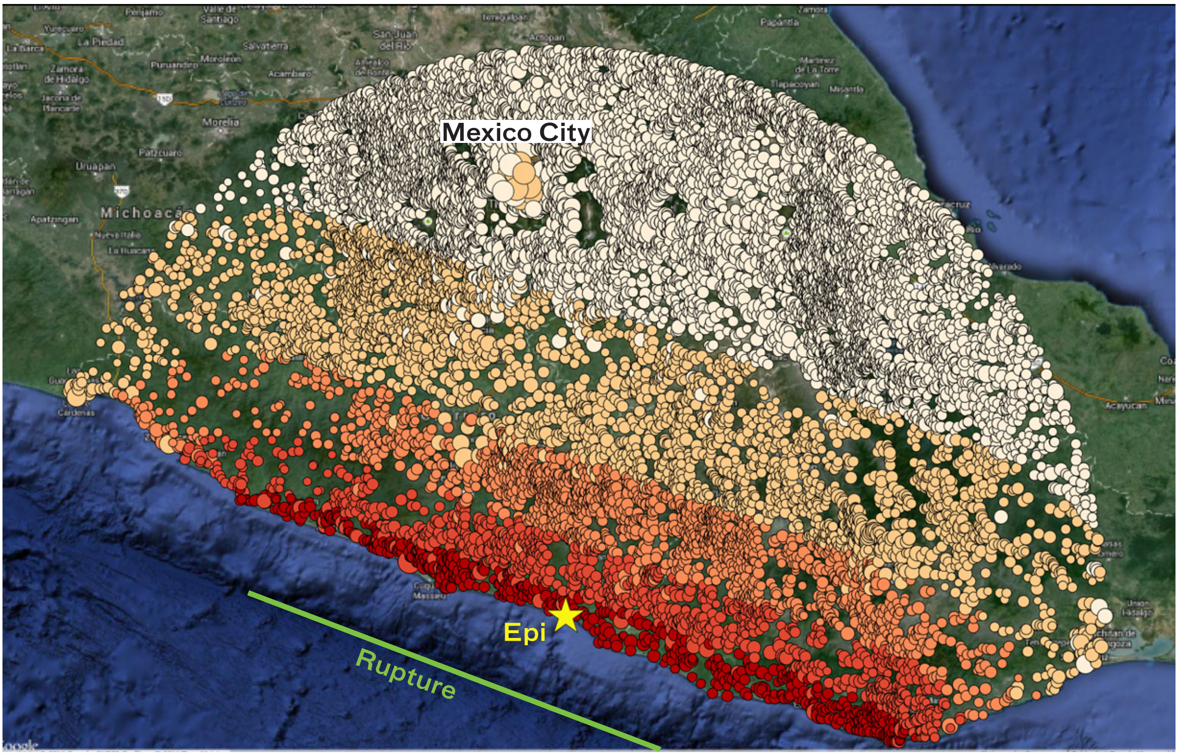

Figure 1: Map of mean damage in settlements within 400 km from the hypothetical epicenter (yellow star), which may result if a largest credible earthquake ruptured the plate boundary along the Pacific coast of Mexico. The rupture length is assumed to be 460 km and the magnitude 9, with hypocentral depth at 25 km. The assumed surface expression of the rupture follows the deepest part of the trench. The damage grade is measured on a scale of 5, from red=major, to white=minor destruction. An exception: In Mexico city the ground motions are enhanced, due to unfavorable soil conditions, hence more severe damage is expected (largest yellow dots), than in surrounding settlements (white). The symbol size is proportional to the logarithm of the population.

Spin offs

The experience gained by issuing predictions of losses at a time when they were unknown, gives me some confidence that I can estimate losses reasonably well, at least within an order of magnitude, often within a factor of 2, in some countries. Therefore, I am in a position to *estimate losses for large future earthquakes*, which are unavoidable, but for which the occurrence time is not known. For example, for the great earthquakes, which are overdue in the Himalaya, I estimate that fatalities will exceed 100,000. A first verification of my estimates occurred on October 5, 2005 in Kashmir (Wyss, 2005). Another example is shown in Figure 1.

Quantitatively estimating the usefulness of mitigating actions before an earthquake has not been possible up to now because one does not know what would have happened without the mitigation. For the first time we have been able to estimate the number of lives saved, using QLARM. In 1975, a Red Guard commander ordered the population to evacuate their homes because large numbers of earthquakes had frightened the population, and some had caused minor damage in Haicheng and surrounding settlements. Subtracting the number of fatalities reported from that calculated by QLARM yielded a life saving of about 8,000 and approximately 27,000 injuries were avoided (Wyss and Wu, 2013) in this M7.3 earthquake.

The detailed data on population by settlements can also be useful for first responders in all kinds of *disasters, such as flooding, landslides and wild fires*. It will be made available through the EU funded IDIRA project (Interoperability of Data and procedures In large-scale multinational Response Actions).

Quantifying the enhanced vulnerability of the rural compared to the urban population, has also become possible for the first time using QLARM. We have modeled the building stock separately in three size categories of population, P (P < 2,000; 2,000 ≤ P ≤ 20,000; 20,000 ≤ P). If these models

Figure 2: In August 2012, two severe earthquakes occurred in the northwestern part of Iran and killed more than 300 people. In such cases, it is very helpful for the authorities to get a quick estimation of the possible losses.

are approximately correct, we can estimate the difference in mortality rate in rural compared to urban built environments. In a first estimate, we found that in Guerrero, Mexico, the rural population is 20% more likely to die in a great earthquake, when at home, than the urban population in events similar to the hypothetical case shown in Figure 1 (Zúñiga et al., 2014). In various other countries this difference ranges from 20% to 97%, depending on the intensity of shaking, and the built environment.

Conclusions

Although the data sets for population and building stock in QLARM are approximate, they rank among the best in the world. The real time alert service is useful because it has furnished first responders with many correct and few incorrect loss estimates within about half an hour of earthquakes worldwide. Based on the experience gained with the real time alerts and using the data sets in QLARM, innovative, new capabilities have been developed. The collaboration with the SED in the real time alert service and the complementary research continues, although there is virtually no funding available.

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