Proceedings of the Conference of the International Communhity on Informatio Systems for Crisis Response and Management, 2006, Newark.

The Kashmir M7.6 Shock of 8 October 2005 Calibrates Estimates of Losses in Future Himalayan Earthquakes

Max Wyss
World Agency of Planetary Monitoring and Earthquake Risk Reduction, 2 rue de Jargonnant; CH-1207 Geneva, Switzerland, tel: +41(0)79 749 4894, wapmerr@maxwyss.com

ABSTRACT

In an article published in March 2005, we estimated the number of fatalities to be expected in future large earthquakes in the Himalaya (Wyss, 2005). For the scenario called "Kashmir", we estimated that 67,000 to 137,000 fatalities should be expected. The M7.6 Kashmir earthquake of 8 October 2005 caused approximately 85,000 fatalities. Thus, one may argue that we forecast this disaster well. However, we assumed M8.1, a depth of 25 km and an epicenter located about 200 km to the SE from the October epicenter. Using the moment tensor solution for the October earthquake with a depth of 12 km for the energy release, we estimate the number of fatalities between 29,000 and 56,000. Thus, a factor of 2 must be applied to obtain the observed number, and the depth of the energy release in the scenario earthquakes should be placed at 12 km, which results in on over-all correction factor of 2.4. Therefore, we correct our estimates for numbers of fatalities in future Himalayan earthquake to range from 100,000 to 500,000, as specified for the locations given in Table 2.

Keywords

Seismic risk, human loss estimates, Himalayan earthquakes.

INTRODUCTION

For a little over three years, we have estimated losses in real time for earthquakes worldwide. In most inhabited parts of the globe, the threshold for reporting an event is M6. At present, we distribute an estimate of the number of fatalities and a map showing the average damage in affected settlements by email, within about 30 minutes of an earthquake. If we judge the consequences as serious, we call persons who wish to be contacted by telephone, to advise them of the extent of the disaster. The purpose of this service is to enable rescue agencies, disaster managers and government officials to make informed decisions concerning rescue operations.

In separate efforts, we estimate loss scenarios for hypothetical earthquakes with high probability of occurring. The purpose of these investigations is to give disaster managers and government officials a quantitative basis to prepare for earthquake disasters. Because we felt that the Himalaya, with its large population, has a high earthquake risk we calculated loss scenarios for seven positions of an earthquake along this thrust belt (Wyss, 2005). Bilham et al. (2004) have shown that several meters of potential slip must have accumulated along most segments of this plate boundary and Khattri (2003) calculated that the probability of at least one great earthquake along the Himalayan thrust this century is 89%. Thus, it seemed that it was time to estimate the number of fatalities and injured that have to be expected in future great Himalayan earthquakes, given current population numbers.

Averaging the moments of the largest historic earthquakes in this area, we assume M8.1 as the typical magnitude to expect. The assumed epicenters were placed along the thrust belt separated from each other by 200 km, except where recent ruptures reduced the current probability of a great earthquake (Figure 1 of Wyss, 2005). The depth of energy release was assumed to be 25 km. We concluded that in the least and most populated segments about 40,000 and 150,000 fatalities, respectively, should be expected and typically 3,000 settlements may be affected.

The westernmost scenario, the "Kashmir" scenario, was given an epicenter about 200 km to the SE of the epicenter of the subsequent M7.6 Kashmir earthquake of 8 October 2005. The range of fatalities for this hypothetical event was given as 67,000 to 137,000 (Wyss, 2005), which brackets the reported number of 85,000. However, because this high number of fatalities was caused by an earthquake with smaller magnitude than the assumed one, we must revise our previous estimates, using the 2005 Kashmir earthquake as calibration.

METHOD

The method of calculating losses is described in detail by Shakhramanian et al. (2000). The important steps in this approach are briefly summarized here. (1) As input, an earthquake hypocenter and magnitude are needed. (2) The intensity of the resulting ground motion is then calculated as a function of distance at every settlement in the data base. (3) The data base contains approximate information on population number and the conditions of the building stock in about one million settlements worldwide. The building properties are specified by fragility curves (e.g. probability of collapse as a function of intensity of shaking) in five building classes and the distribution of the buildings in these classes. (4) The program calculates the expected distribution of the resulting damage in six categories, ranging from minor damage to collapse. (5) Based on assumed probabilities that a given calculated damage will result in death or injury of the occupants, the number of fatalities and injured is then calculated. (6) The method is calibrated by comparison of the estimates with numbers of fatalities reported in past earthquakes.

The number of fatalities is the quantity we use as calibration factor, because it is the best known measure of the extent of earthquake disasters. Unfortunately, there are various reasons why local governments sometimes exaggerate and sometimes artificially reduce the number of fatalities. In other cases, the number of victims is simply not accurately known. Therefore, we have to keep in mind that all the work and the calibrations reported here are approximations.

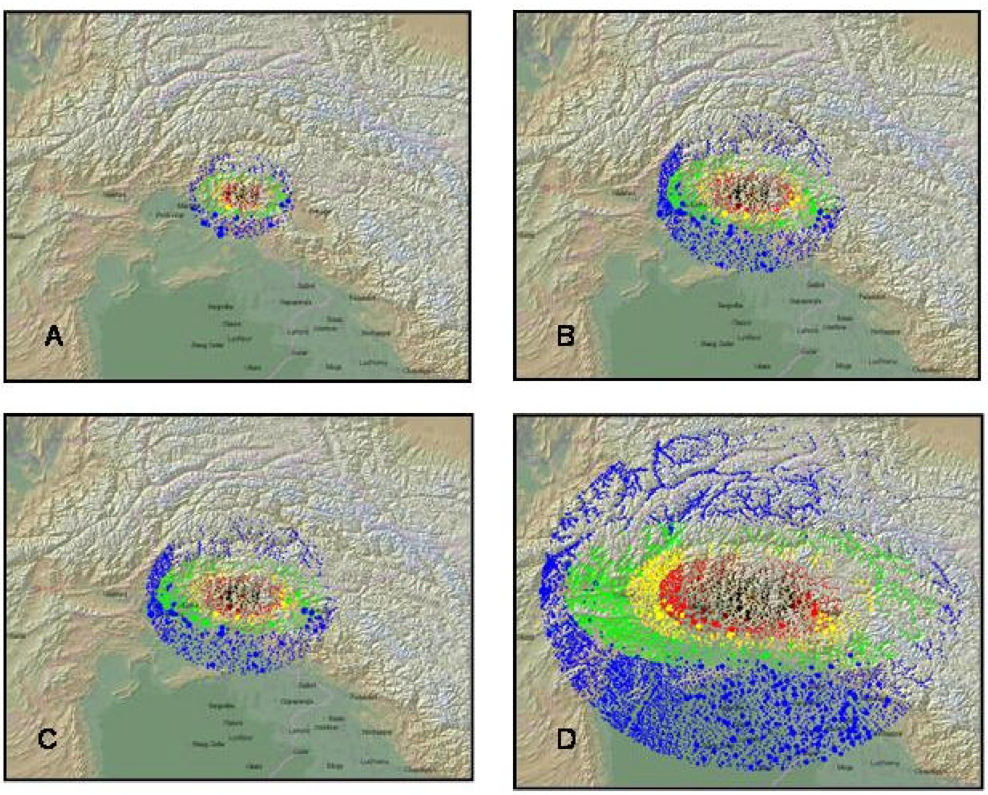

Figure 1: (A) – (C) Map of estimated mean damage to buildings in the settlements affected by the strong shaking due to the M7.6 Kashmir earthquake of 8 October 2005. Size of dots proportional to population. Hypocenter and attenuation of seismic waves varied according to Table 1. (D) Estimated damage if this earthquake had been of the largest credible magnitude M8.5.

PREVIOUS WORK

The many uncertainties that exist in the parameters necessary to calculate losses due to earthquakes render these estimates very approximate in developing countries. For example, the transmission properties for seismic waves and the local soil conditions are not, or poorly, known. Also, the composition and quality of building stock are known only approximately, and population numbers typically lag behind current values. Therefore, we tested the capability of the computer program and data set in our tool QUAKELOSS to estimate numbers of fatalities in earthquakes on the sub-continent correctly, before we embarked on the scenario calculations. It turned out that in 15 out of 16 available examples QUAKELOSS estimated fatalities correctly (Table 1 in Wyss, 2005). Based on this result, we proposed that it was reasonable to attempt loss estimates for future, hypothetical earthquakes in this area.

The assumed epicenters were placed at arbitrary locations, separated by the dimension of a rupture length of a typical M8.1 earthquake. No epicenters were place in segments that had been judged of low current slip accumulation (Bilham et al., 2004) and the study area was terminated at the eastern and western end where previous studies (Bilham et al., 2004, Khattri, 2003) had stopped.

One of the assumptions in the current, primitive stage of loss estimates is that under- and over-estimates in different locations average out and that the sum total of the losses may be relatively reliably estimated. We do not yet attempt to differentiate the correctness of estimates for individual settlements or for different neighborhoods in large cities.

LOSS ESTIMATES FOR THE M7.6 KASHMIR EARTHQUAKE OF 2005

Three estimates are shown for the losses in the M7.6 Kashmir earthquake of 2005 (Table 1 and Figure 1). The first example shows the results, using the first reviewed location distributed by the US Geological Survey (received by us 31 minutes after the earthquake), together with the assumption of high attenuation of wave propagation in the region. This is the most conservative calculation we made in real time and it is this map (Figure 1A) that we placed on our webpage at the time. A less conservative picture emerges when attenuation is assumed to be low (B in Table 1 and Figure 2B). As example C, we show the loss estimate, based on the “best” after-the-fact moment tensor solution for the position of the centroid energy release (Harvard webpage) with low attenuation. This yields the highest estimate of fatalities.

To illustrate what could have happened, we added the example D of an earthquake with an assumed largest likely magnitude for the Himalayan thrust belt, M8.5, and epicenter coordinates as the event on October 8.

	Parameters	Lat. (deg.)	Lon. (deg.)	Depth (km)	Mag.	Estimated Fatalities (thousands)
A	Real time, high attenuation	34.40	73.50	10	7.6	7 - 14
B	Real time, low attenuation	34.40	73.50	10	7.6	27 - 52
C	Best solution (Mo tensor)	34.37	73.47	12	7.6	29 - 56
D	Maximum likely magnitude	34.37	73.47	12	8.5	143 - 291

Table 1: Estimated number of fatalities for the 2005 Kashmir M7.6 earthquake, using different input for hypocenter and transmission properties for seismic waves, plus an estimate for the fatalities in an earthquake with a maximum credible magnitude of 8.5.

DISCUSSION

The real time loss estimate after the 2005 Kashmir M7.6 earthquake issued by us was a success, although we formulated the warning along the most conservative lines. The stated responsibility in real time warning is to differentiate between disastrous earthquakes and those without serious consequences. The threshold between the two cases is given by the number of fatalities and injured that can be handled by local rescuers. When we report a "serious disaster" with "thousands of fatalities" and "more than 10,000 injured", our sponsor, the Swiss Humanitarian Aid Rescue Unit, mobilizes and offers help to the country affected. It is not necessary to calculate the exact extent of the disaster within less than an hour. However, to help the injured effectively, an early start of the mobilization is a must.

The comparison of the number of fatalities estimated using the "best" source and transmission parameters (42,500, Table 1) with the reported number (85,000) shows that we underestimated the fatalities by a factor of 2. Considering all the uncertainties, this is a satisfactory result. The difference could be due to amplification of the strong motion through unknown soil conditions, due to fragility properties of the built environment inferior to the ones assumed in our data base and due to population numbers larger than in the data base.

The implications for our previous scenarios by this test case is that those estimates must be corrected by a factor of 2.4. A factor of 2 comes from the comparison of our "best" estimate and the reported number of fatalities, discussed in the previous paragraph. In addition a factor of 1.2 brings the numbers estimated for energy release at 25 km depth (the assumption in our previous work) to the numbers expected for a depth of 12 km as used in the "best" estimate and as derived by the moment tensor solution for the earthquake source. After the correction, the scenario loss estimates suggest that in the mildest scenario (W. Nepal) about 40,000 and in the most serious one (in the Dehra Dun segment) about 350,000 fatalities should be expected (Table 2).

The correction factor of 2.4 should not be taken as a well defined number. All loss scenarios we calculate are order of magnitude estimates. The soil conditions and, source depth and building properties in Pakistani Kashmir may be different than in other parts of the Himalaya. Therefore, this one calibration event may not accurately represent conditions everywhere in the Himalaya. The amplification factor of 2.4 is simply the best estimate we have and we use it with the understanding that the resulting corrected loss calculations (Table 2) are still only order of magnitude estimates.

	Location.	Lat. (deg.)	Lon. (deg.)	Depth (km)	M	Expected Fatalities Corrected (thousands)
1	Assam	27.8	92.3	12	8.1	58 - 118
2	Bhutan	27.3	89.5	12	8.1	182 - 362
3	Katmandu	28.1	84.2	12	8.1	50 - 101
4	W. Nepal	28.7	81.8	12	8.1	26 - 53
5	Garhwal	29.7	79.6	12	8.1	139 - 276
6	Dehra Dun	30.7	77.7	12	8.1	230 - 478
7	Kashmir	33.0	75.0	12	8.1	161 - 329

Table 2: Numbers of expected fatalities in future Himalayan earthquakes corrected by multiplication with a factor of 2.4 derived here (original estimates in Table 2 of Wyss, 2005)

The number of injured is usually a factor of 2 to 3 larger than that of fatalities. This suggests that up to 1 million injured may have to be treated in a future great Himalayan earthquake. Although we are trying to emphasize conservative estimates, we must note that the magnitude of 8.1, selected for the scenarios, can be significantly exceeded in future ruptures because M8.5 and 8.7 earthquakes have occurred in the past. When these types of earthquake occur again the numbers of injured and homeless will be truly staggering.

CONCLUSIONS

It is concluded that disastrous earthquake can be distinguished from inconsequential ones within less than an hour after the event. This is important for rescue operations because for long periods (days) information usually does not flow from the hardest hit areas to the outside.

The extent of the Kashmir disaster was forecast with satisfactory accuracy by scenario loss estimates published seven month before the October 2005 Kashmir earthquake. However, this test case suggests that a multiplication factor of 2.4 should be applied to the numbers of fatalities estimated in the scenario cases for future Himalayan earthquakes by Wyss (2005). This means that several hundred thousand and up to 1 million injured are expected in future great Himalayan earthquakes.

ACKNOWLEDGMENTS

This work was in part supported by the Humanitarian Aid and Swiss Humanitarian Aid Unit of the Swiss Agency for Development and Cooperation, and I thank Sergei Sushchev of the Extreme Situations Research Center, Moscow, for supplying the computer code and data set QUAKELOSS to WAPMERR.

REFERENCES

1. Bilham, R., Gaur, V. K. and Molnar, P. (2001) Himalayan seismic Hazard, *Science*, **293**, 1442-1444.
2. Khattri, K. N. (2003) personal communication.
3. Wyss, M. (2005) Human losses expected in Himalayan earthquakes, *Natural Hazards*, **34**, 305-314. (DOI: 10.1007/s11069-004-2073-1).
4. Shakhramanian, M. A., Larionov, V. I. , Nigmetov, G. M. and Sutschev, S. P. (2000), pp. 179, Assessment of the seismic risk and forecasting consequences of earthquakes while solving problems on population rescue, ed. M. Shakhramanian, Moscow, ISBN 5-93970-007-1.