CASUALTY IN EARTHQUAKE AND TSUNAMI DISASTERS: INTERNET-BASED MONITORING AND EARLY ESTIMATION OF THE FINAL DEATH TOLL

Y.Z. Zhao[1], Z.L. Wu[2] and Y.T. Li[2, 3]

[1] *College of Earth Science, Graduate University of Chinese Academy of Science, Beijing, China*
[2] *Institute of Geophysics, China Earthquake Administration, Beijing, China*
[3] *Earthquake Administration of Liaoning Province, Shenyang, China*
Email: wuzl@cea-igp.ac.cn

ABSTRACT :

We investigated the time-dependent number of deaths reported through internet after earthquakes and/or tsunamis based on our previous model and the new results of earthquake cases. A model $N(t) = N_0\,[1 - \exp(-\alpha t)]$ is used to describe such a temporal variation, in which $N(t)$ is the number of deaths reported at time t, N_0 is the final number of deaths, and α is the coefficient reflecting the rescue process. We considered 19 earthquake cases since 1999 using the information from http://www.sina.com.cn, which shows that the model fits the data well, and the logarithm of α is reversely proportional to the surface wave magnitude of earthquakes. Early estimation of the range of the final death toll can be made using the empirical magnitude-dependent coefficient α.

KEYWORDS: Casualties, Earthquake, Earthquake-generated tsunami, Internet

1. INTRODUCTION

Fatality caused by disastrous earthquakes and/or earthquake-generated tsunamis is one of the focuses of concern in either rescue actions or earthquake aid practice. Since recent years, development of internet has made it possible to use the on-line news for a near real-time monitoring of the number of deaths reported after an earthquake, and, in some cases, implement an early estimation of the final death toll.

Various studies have been conducted investigating the regularities of human casualties during disastrous earthquakes (Lomnitz, 1970; Samardjieva and Oike, 1992; Tsai et al., 2001; Samardjieva and Badal, 2002; Ashkenazi et al., 2005; Badal et al., 2005; Gao and Jia, 2005; Liu and Wu, 2005a, b; Gutiérrez et al., 2005; Wyss, 2005; Koshimura et al., 2006; Lamontagne, 2008). The regularities revealed and the lessons related are useful for the reduction of natural disasters in future. In this study we try to investigate the temporal changes of fatalities reported after earthquakes and/or earthquake-generated tsunamis. This problem was noticed firstly by Gao and Jia (2005). Modifying the data fitting of Gao and Jia (2005) and based on the case of the 2004 Indian Ocean earthquake-generated tsunami and the 2005 Pakistan earthquake, Liu and Wu (2005a) propose a model with clear physical significance, that the time-dependent number of deaths $N(t)$ can be represented by

$$N(t) = N_0\,[1 - \exp(-\alpha t)] \tag{1.1}$$

in which N_0 and α are constants. Taking the derivative of Equation (1.1),

$$dN/dt = \alpha\ (N_0 - N) \tag{1.2}$$

where the term on the left-hand side is the rate of discovering dead bodies, and the term $(N_0 - N)$ on the right-hand side is the dead bodies remained undiscovered, the physical significance of the model is clear. Using this model to make an early estimate of the final death toll is difficult due to the nature of the equation if the two unknown parameters are to be determined at the same time (Liu and Wu, 2005b). To remedy this problem, in this investigation, we use this model to a number of earthquake cases, and try to study whether there is a relation between the coefficient α and the magnitude of the earthquake.

2. DATA USED FOR ANALYSIS AND TEST OF THE PREVIOUSLY PROPOSED MODEL

We consider 19 cases of earthquakes and/or earthquake-generated tsunami, as shown in Table 1. From the news archive of the special reports on each earthquake and/or earthquake-generated tsunami, we pick out the news related to the death toll and put them altogether to see how the number varies with time. Single media source (http://www.sina.com.cn) is purposely selected to ensure the consistency of the database. For reports in the form of 'the death toll is at least *X*', we simply take *X* as the value of data at that moment.

Table 1 Cases of earthquakes and/or earthquake-generated tsunami considered in this investigation

No.	Date UTC	Place	Magnitude / M_S	Casualty
1#	1999-08-17	Izmit, Turkey	7.8	17118
2	2001-01-13	EL Salvador	7.8	844
3	2001-02-13	EL Salvador	6.5	315
4#	2001-06-23	Moquegua, Peru	8.2	74
5#	2002-02-03	Afyon, Turkey	6.4	44
6#	2002-06-22	Qazvin, Iran	6.4	261
7	2003-05-01	Bingol, Turkey	6.4	177
8	2003-05-21	Northern Algeria	6.9	2266
9	2003-12-26	Bam, Iran	6.8	31000
10	2004-02-24	Al Hoceima, Morocco	6.4	628
11#	2004-05-28	Northern Iran	6.3	35
12	2004-12-26	Sumatra, Indonesia	8.8	283100
13	2005-02-22	Central Iran	6.5	612
14#	2006-03-31	Western Iran	6.0	70
15	2006-05-26	Java, Indonesia	6.2	5749
16	2006-07-17	Java, Indonesia	7.2	413
17#	2007-03-06	Sumatra, Indonesia	6.4	67
18	2007-08-15	Pisco, Peru	7.9	514
19	2008-05-12	Wenchuan, China	8.1	69185

Note: Earthquake parameters and casualty are from
http://earthquake.usgs.gov/eqcenter/eqarchives/significant/
The 'bad' cases are labeled by #, see Figures 1 and 2.

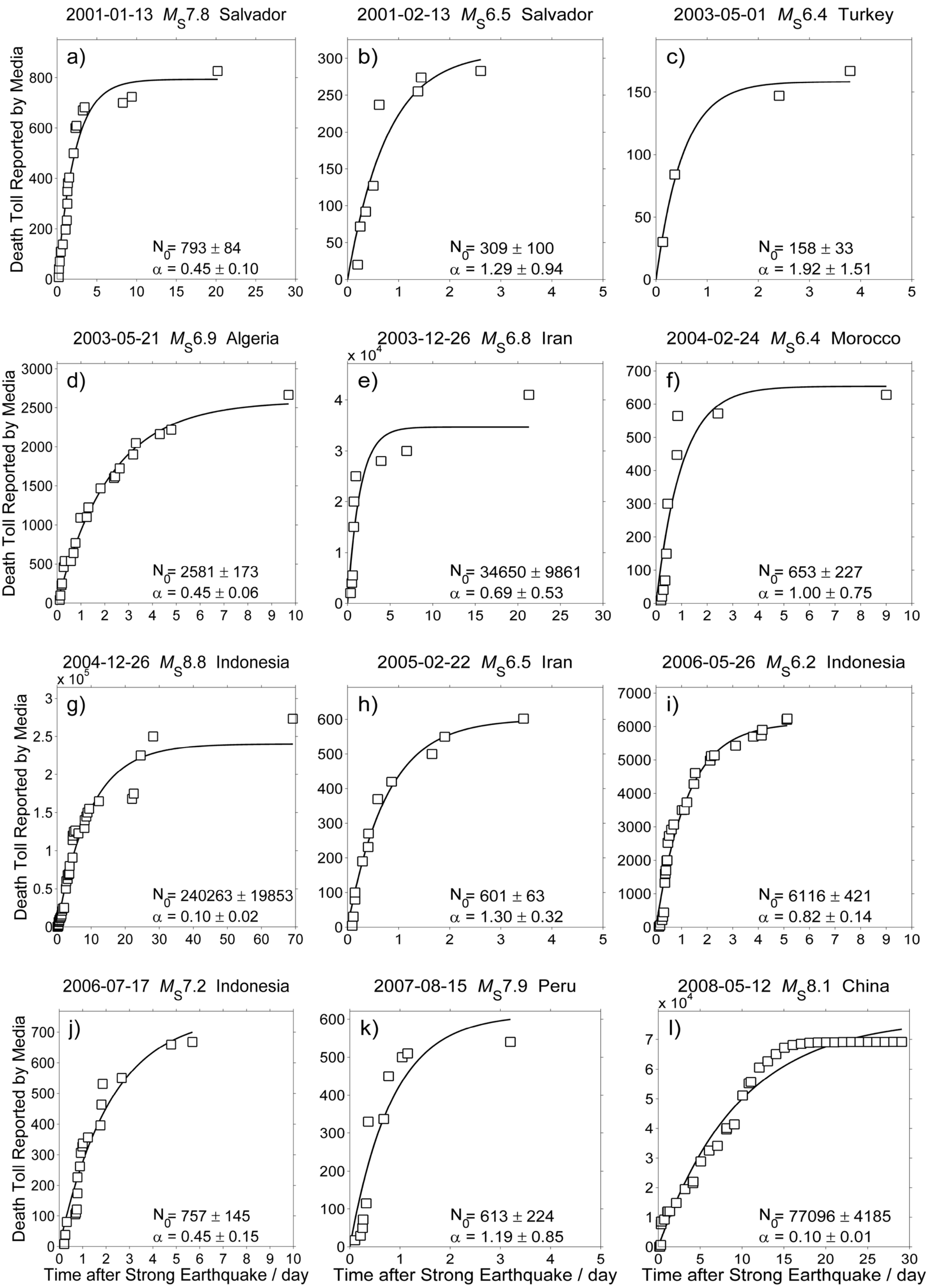

Figure 1 Temporal variation and fitting of death toll reported by Internet for the 12 'good' cases.

The 19 cases can be divided into two classes: ‘good’ cases, as shown in Figure 1, posses the ‘whole process’ and can be fitted by Equation (1.1), and ‘bad’ cases, as shown in Figure 2, have only an apparently linear increase trend, with only a few data points available. Figure 1 shows the fitting of the ‘good’ cases. We use non-linear curve fitting function in MatLab to determine the parameters in Equation (1.1) for each case. From Figure 1 it can be seen that the model curve (solid line) fits the real data (open squares) fairly well, indicating that the model described by Equation (1.1) holds for these earthquake cases.

The ‘bad’ cases are mainly due to the lack of data available. For the ‘bad’ cases, the fitting by Equation (1.1) is not valid. As a rough estimation, we take the half of the final number N_0 to determine the value of α via

$$\exp(-\alpha T) = 0.5 \tag{2.1}$$

where T is the time when the number of death $N(T)$ reaches half of the final number N_0.

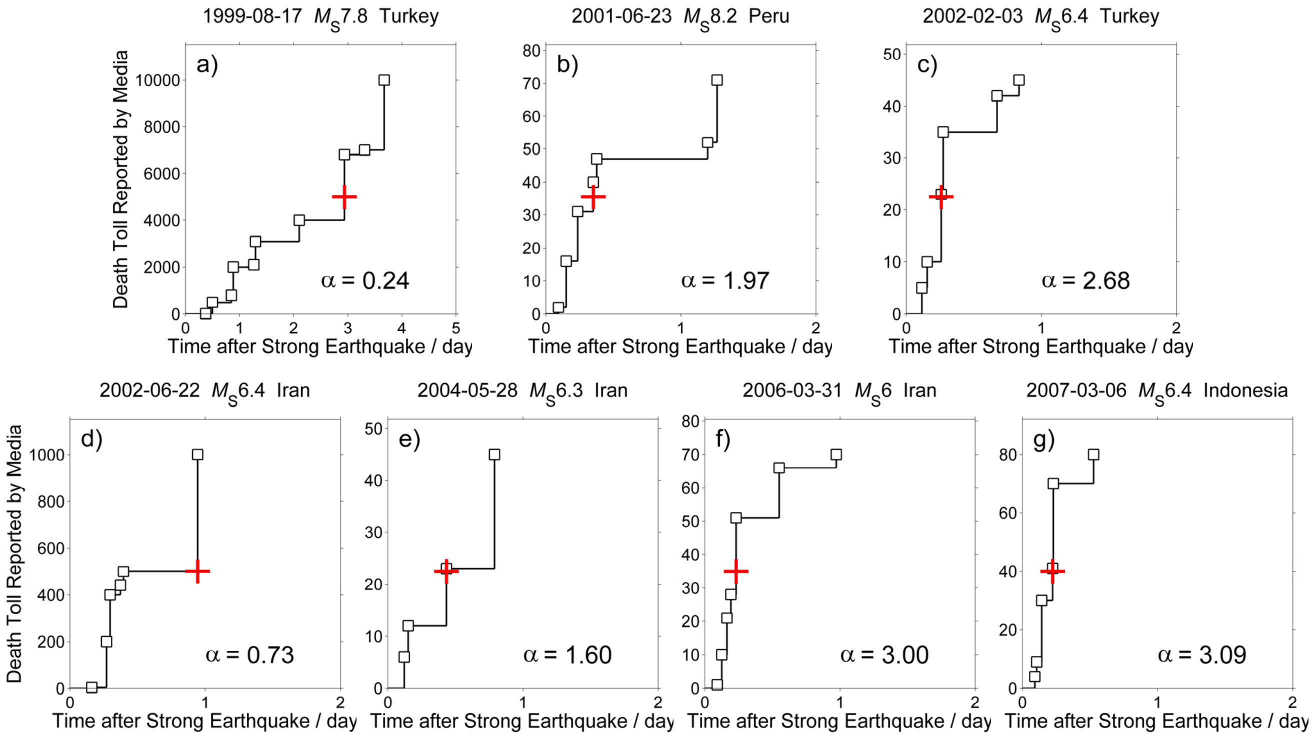

Figure 2 Temporal variation of death toll reported by Internet from the 7 ‘bad’ cases. Red cross indicates T, the time when the number of death $N(T)$ reaches half of the final number N_0.

3. RELATION BETWEEN THE COEFFICIENT α AND THE MAGNITUDE OF EARTHQUAKE

Temporal variation of found casualties and estimation of the final number of fatalities directly affect the deployment of task forces for emergency response and the organization of rescue actions. As shown by Liu and Wu (2005b), estimation of final death toll using Equation (1.1) is not reliable until several days after the earthquake, therefore reducing the free parameters to be determined is important in facilitating the estimation. For this purpose we study the relation between coefficient α and the magnitude of earthquakes. Figure 3a shows the α-M_S relation for the 12 'good' cases, and Figure 3b shows the relation for both the 12 'good' cases and the 7 'bad' cases. It can be seen that although the data points are scattered, there is a clear trend of decrease of the logarithm of coefficient α with the magnitude of the earthquake. Physically, this relation is understandable because the bigger the earthquake, the more difficult the rescue practice will be.

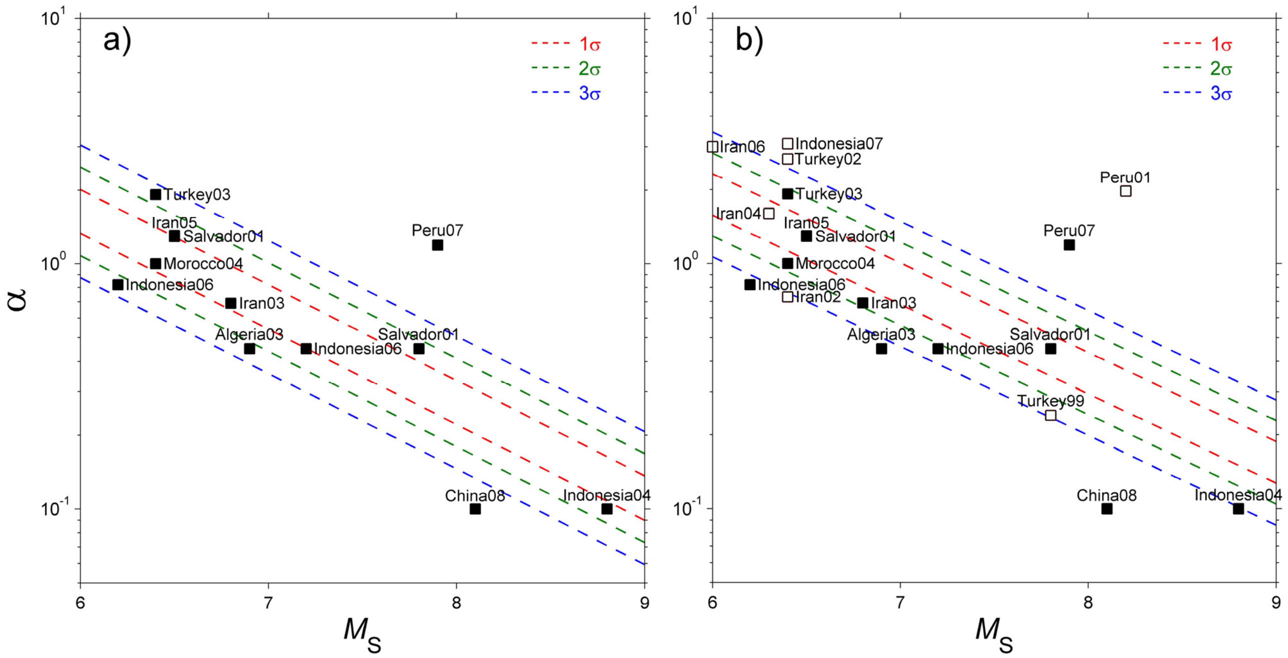

Figure 3 Relation between coefficient α and magnitude of earthquake. Since earthquake destruction are mainly caused by high-frequency seismic waves, and also considering the problem of magnitude saturation for large earthquakes, we use surface wave magnitude to denote the size of the earthquake. a) Result for the 12 'good' cases as listed in Table 1. b) Results for both the 12 'good' cases and the 7 'bad' cases. Data fitting is shown by dashed lines.

4. CONCLUDING REMARKS AND DISCUSSION

In this investigation we try to figure out how the found casualties varying with time and model its time-dependent behavior. From the 12 'good' cases as shown in Figure 1 it can be seen that although the data is scattered to some extent, the temporal variation is apparently characterized by a fast increase at the early stage and then a slower increase followed, showing a curve with saturation characteristics, obeying the equation proposed by Liu and Wu (2005a). One of the key problems is whether the final number of fatalities could be estimated earlier so as to facilitate the deployment of task forces for emergency response. For reducing the free parameters we further investigated the relation between coefficient α and the magnitude of earthquake. We found that the logarithm of α decreases with the surface wave magnitude of earthquake. Thus in practice one can have the 'most optimal' estimation and the 'most pessimistic' estimation, or an 'average' estimation, according to the magnitude of the earthquake. This is naturally not ideal, but it is the best we can do at the present time. Comparing to those 'static' methods which used the relation between magnitude/intensity and the final death toll to 'predict' the later (e.g., Lomnitz, 1970; Samardjieva and Oike, 1992; Samardjieva and Badal, 2002; Wyss, 2005), our 'dynamic' approach has the function of 'adjusting' the final result with time according to new reports, and thus can be used as a complementary tool of the 'static' approaches.

In this study, what we collected is the data from news media. Obviously the data from news media has problems with its accuracy and reliability. Data sources varied in the reports, causing even larger uncertainties to the data. In some earthquakes, such as the 2004 Sumatra earthquake, inconsistency existed even for data published by different governmental agencies. As a matter of fact, comparing the final death toll from USGS as listed in Table 1 and the last number of death reported by news media as shown in Figures 1 and 2, such an uncertainty is obvious. On the other hand, however, in the deployment of task forces for the rescue practice, it is more important to know the 'order of magnitude' of the death toll, even if it is inaccurate.

REFERENCES

Ashkenazi, I., Isakovich, B., Kluger, Y., Alfici, R., Kessel, B. and Better, O. S. (2005). Prehospital management of earthquake casualties buried under rubble. *Prehospital and Disaster Medicine* **20:2,** 122-133.

Badal, J., Vázquez-Prada, M. and González, Á. (2005). Preliminary quantitative assessment of earthquake casualties and damages. *Natural Hazards* **34:3,** 353-374.

Gao, J. G. and Jia, Y. (2005). A study on the time of promulgating earthquake disaster - An index of earthquake rescue ability. *Journal of Catastrophology* **20:1,** 31-35 (in Chinese with English abstract).

Gutiérrez, E., Taucer, F., Groeve, T. D., Al-Khudhairy, D. H. A. and Zaldivar, J. M. (2005). Analysis of worldwide earthquake mortality using multivariate demographic and seismic data. *American Journal of Epidemiology* **161:12,** 1151-1158.

Koshimura, S., Katada, T., Mofjeld, H. O. and Kawata, Y. (2006). A method for estimating casualties due to the tsunami inundation flow. *Natural Hazards* **39:2,** 265-274.

Lamontagne, M. (2008). Casualties directly caused by an earthquake in Canada: First contemporaneous written accounts from the M6.5 Charlevoix, Quebec, earthquake of 20 October 1870. *Bulletin of the Seismological Society of America* **98:3,** 1602-1606.

Liu, Z. and Wu, Z. L. (2005a). A simple model of reported casualties during earthquakes and earthquake-generated tsunamis. *Earthquake Research in China* **21:4,** 526-529 (in Chinese with English abstract).

Liu, Z., Wu, Z. L., Cai, M. J. and Jiang, C. S. (2005b). Discussion on casualties during 2004 earthquake-generated tsunami in Indian Ocean. In: Li, S. C., Wang, Y. J. and Huang, P. eds., Progress in Safety Science and Technology, Vol. 5, Science Press, Beijing, China, 2075-2077.

Lomnitz, C. (1970). Casualties and behavior of populations during earthquakes. *Bulletin of the Seismological Society of America* **60:4,** 1309-1313.

Samardjieva, E. and Badal, J. (2002). Estimation of the expected number of casualties caused by strong earthquakes. *Bulletin of the Seismological Society of America* **92:6,** 2310-2322.

Samardjieva, E. and Oike, K. (1992). Modelling the number of casualties from earthquakes. *Journal of Natural Disaster Science* **14:1,** 17-28.

Tsai, Y. B., Yu, T. M., Chao, H. L. and Lee, C. P. (2001). Spatial distribution and age dependence of human-fatality rates from the Chi-Chi, Taiwan, earthquake of 21 September 1999. *Bulletin of the Seismological Society of America* **91:5,** 1298-1309.

Wyss, M. (2005). Human losses expected in Himalayan earthquakes. *Natural Hazards* **34:3,** 305-314.