Statistical analysis of the 1999 Chi-Chi, Taiwan, aftershock sequence based on a modified Reasenberg-Jones model

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Abstract

The b value in the frequency-magnitude distribution of the aftershock sequence of the 1999, M_w=7.6, Chi-Chi, Taiwan, earthquake is found to be dropdown and then gradually back to its background value. This observation suggests a time-dependent frequency-magnitude distribution of the Chi-Chi aftershocks. Therefore, we consider a modification of the Reasenberg-Jones model [Reasenberg and Jones, 1989, 1994], denoted as MRJ model, hereafter, for assessing the temporal-spatial hazard of the Chi-Chi aftershocks. A study of the association between the predicted aftershock hazard and the occurrence of future aftershocks demonstrates that the MRJ model is helpful for the evaluation of the earthquake hazard in a short time after the Chi-Chi mainshock.

Introduction

The frequency-magnitude distribution of earthquakes generally follows the Gutenberg-Richter law [Gutenberg and Richter, 1944]:

$$\log_{10} N(M) = a - bM, \text{ for } M \geq M_c$$

Note that the *b* value, as one of the most important parameter in seismology, has been observed to vary temporally and spatially [Utsu, 1971; Smith, 1981; Wiemer and Wyss, 1997; Wiemer and Katsumata, 1999].

On the other hand, the occurrence rate of aftershock at time *t* after the mainshock is usually described by the Utsu-Omori power law [Utsu et al., 1995]:

$$\lambda(t) = \frac{K}{(t+c)^p}$$

Assuming that magnitude and time of earthquakes are independent, a multiple of the Gutenberg-Richter law and the Utsu-Omori power law leads to the RJ model [Reasenberg and Jones, 1989; 1994] for describing the time-magnitude distribution of aftershocks.

However, it was recognized that the magnitude distribution could depend explicitly on time [Ogata, 1989; Vere-Jones, 1992]. Moreover, it is usually believed that large aftershocks are more hazardous to occur right after its mainshock, but they tend to have a small chance to occur when time goes by. In fact, the *b* value is shown to be a function of time for the 1999 Hector Mine aftershock sequence [Wiemer et al., 2002]. A similar result is also obtained for the aftershock sequence of the Chi-Chi earthquake as shown in Figure 1 herein. Therefore, a time-dependent frequency-magnitude distribution of aftershocks is needed which motivates a modification of the original RJ model.

In this study, we modified the RJ model by incorporating with a linear trend in log-time for the *b* value in for describing the aftershock hazard post to the 1999, Mw=7.6, Chi-Chi earthquake. We then make a comparison of the modified and original RJ models for sequentially predicting tomorrow's Chi-Chi aftershocks in the study region. We also show how to alarm the possible rupture area of future Chi-Chi aftershocks based on the MRJ model. Finally, we investigate the association between the MRJ model-based alarming area and the rupture area of future aftershocks.

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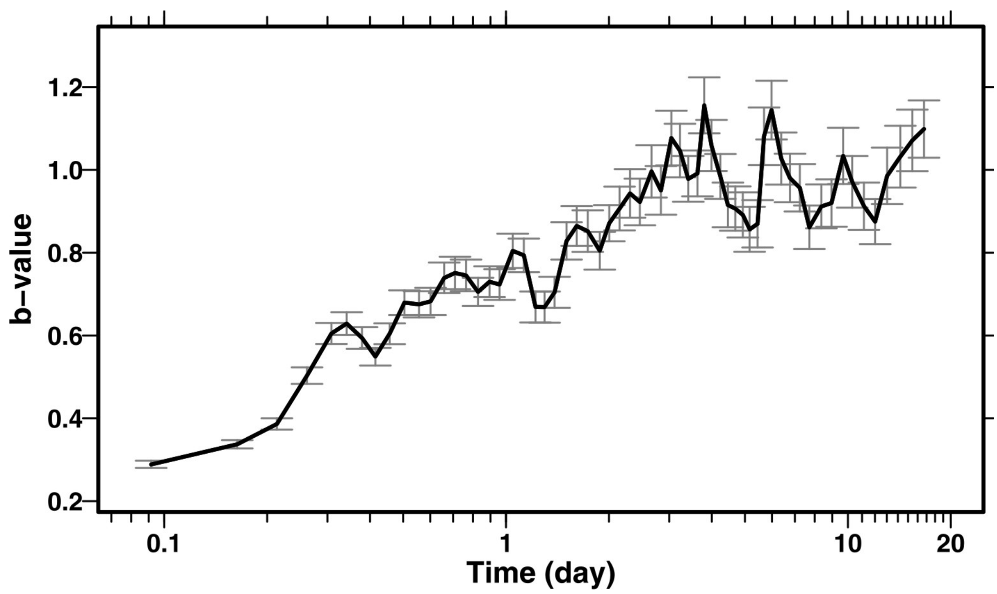

Figure 1. The time-varying b values for the aftershocks 12 hours after the Chi-Chi earthquake. The b values and the associated standard errors are computed based on a moving time-window containing 250 $M \geq 2.5$ aftershocks sliding by 100.