# A detailed study of the unified scaling law of earthquake occurrence

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## Abstract

The unified scaling law (also called the BCDS model), merges (1) Omori Law, (2) Gutenberg-Richter law, and (3) geometrical fractal distribution of epicenters, all investigate the occurrence of earthquakes from a spatial-temporal perspective. This study plans to verify important questions arising from the definition of the BCDS model by doing three experiments: First, understand the feasibility of applying this model to Taiwan by using different cell sizes and cut-off magnitude. Second, ascertain the differentiation between aftershocks and main shocks in a unified scaling law by comparing undeclustered earthquake time sequences with declustered ones. Third, investigate the differences among the scaling relationships obtained from various geological settings in Taiwan.

Our results show that no matter how cell size and cut-off magnitude change, they produce a very similar pattern symbolizing the scaling law. After declustering, the constant part that indicates the characteristic of the aftershock apparently disappears, and the slope of the fast decaying part that corresponds to the main shock remains almost the same. In addition, the scaling laws obtained from four different sub-regions in Taiwan, although slightly different to each other, all show a similar scaling law.

Therefore the following conclusion is drawn: It is feasible and practical to use the BCDS model for interpreting the occurrence of complicated spatial-temporal earthquakes. Furthermore, the result of the differentiation of main shocks and aftershocks extends the nature of this model.

## Introduction

The nature of the spatial-temporal phenomenon of earthquake occurrences is a complicated one. It is easier as well as more important for seismologists to understand the correlation among earthquakes over a long period of time than it is to just study an individual isolated earthquake. Despite the complexity of the phenomenon, several clues in some studies must be examined in detail to regulate this situation. First, when looking at it from the relationship between time and earthquakes, Omori's Law

(Omori, F., 1895) states that the frequency of aftershocks decreases with time after a main shock, thereby precisely indicating the existence of a power law. Similarly, when we look at the relationship of earthquake occurrences from the point of time and space, it illustrates the appearance of a power law that can be deduced from the Gutenberg-Richter law (Gutenberg, et al., 1944). In it the frequency of earthquake occurrences changes with the magnitude threshold of the earthquakes occurring in a certain area. These two power-law relationships between the waiting time and the magnitude of earthquakes can be considered as a form of scale invariance of time and energy. This scale invariance is also shown in the space distribution of earthquakes. In other words, the spatial distributions of the epicenters of earthquakes are fractal, but random (Okubo, et al., 1987, Kagan, 1994, Marsan, et al., 2000).

Consequently, the following deduction can be made from the above statistics: although the phenomena of earthquakes display a complex spatial-temporal behavior, several self-similarity properties are found in the statistics of earthquakes. The studies by Bak et al., (2002) and Christensen, et al., (2002) primarily proposed an innovative method, called the BCDS model, to interpret the spatiotemporal distribution of earthquakes by merging (1) Omori's Law, (2) the Gutenberg-Richter law, and (3) the geometrical fractal distribution of epicenters; thereby creating a unified scaling law. In brief, only a critical phenomenon exhibits a power law; that is, the hypothesis notes that earthquake occurrences can be considered as self-organized critical (SOC) (Bak, et al., 1988) phenomena.

The ingenious result of Bak et al., (2002) has raised other discussions and further research (Corral, Á., 2004; Corral, Á., 2005; Lindman, et al., 2005). Some scientists redefined the procedure of BCDS to investigate the earthquakes in their own area. At the same time we introduce this theory to analyze and better understand the earthquakes in Taiwan and hope to come a step closer to verifying the following issues: 1. how can the intrinsic characteristic seismicity in Taiwan be regulated by this scaling law? 2. how feasible it is to use this model to precisely define the main shock and the aftershocks? 3. Is this scaling law appropriate to be applied to Taiwan's complicated geological and tectonic structure?

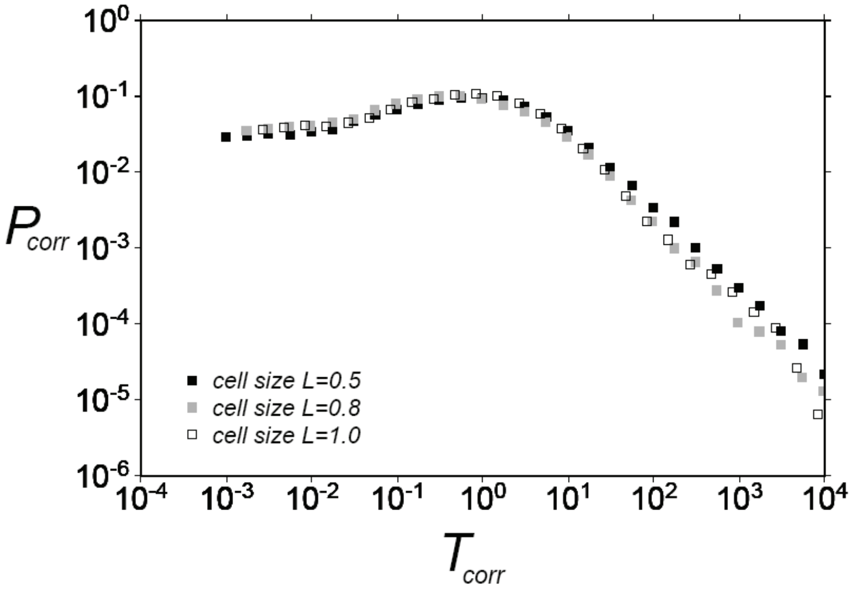


Fig 1.The plot of $P_{corr}$ vs $T_{corr}$ based on the BCDS model using earthquakes in Taiwan with a cut-off magnitude $M_c$=2.0 for varying cell sizes, L .

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