Beyond Omori: Continuous mapping of energy release during the Kaikoura Mw7.8 earthquake sequence

*Bill Fry[1], Matthew Charles Gerstenberger[1], Honn Kao[2]

1. Tectonophysics Department, Natural Hazards Division, GNS Science, New Zealand, 2. Natural Resources Canada, Pacific Geoscience Center

The Omori Law, has greatly influenced the field of seismology since its publication in 1894. The law describes the fundamental nature of earthquakes as patterns of a large earthquakes followed by aftershocks. The modified-Omori Law remains a cornerstone of modern seismology more than 100 years after its discovery. This law is based on the assumption that aftershock generation processes are represented by traditional catalogues of earthquake magnitudes and locations. There are many reasons to believe this fundamental assumption is wrong. We have begun to delve deeper into the understanding of these earthquake processes by looking beyond catalogues. We quantity basic physical measurements that directly relate ground motions recorded by seismometers on the Earth surface to energy released within the earth. By quantifying this energy release through time and space, we are attempting to develop a more accurate view of the seismological process by circumventing problems associated with standard earthquake catalogues.

Omori decay has been shown to vary significantly between earthquake sequences. Often, the modified-Omori Law is combined with the Gutenberg-Richter Relation to describe not just the decay in numbers of earthquakes, but also the distribution of earthquake magnitudes. It is our controversial contention that the use of traditional earthquake catalogues to define these relations is inadequate because of three main shortcomings. 1) Quantifying the huge number of discrete earthquakes in the seconds and minutes following a big earthquake is at least difficult, and perhaps impossible. 2) The different magnitude scales used to quantify earthquake are inconsistent. For example, Richter magnitude calculation works well for small earthquakes, but not large ones; Moment magnitude calculation works well for large earthquakes but not small ones. Unfortunately, Richter magnitude and moment magnitude measure different quantities. 3) Traditional earthquake catalogues do not do not detect many newly discovered ‘slow earthquakes’. Many of these slow earthquakes release seismic energy, but that energy is also not captured by traditional magnitude measures. We attempt to overcome these limitations by quantifying the behaviour of the Earth during an earthquake sequence by looking at the most fundamental measurement of Earth's deformation, the release of energy. To do this, we back project ground motions recorded by seismometers to continuously quantify the amount and location of energy released by the earth. As back projection is a non-unique solution to the energy radiation problem, we impose mapping criteria to minimize the duplicate counting of large energy envelopes.

The recent Kaikoura Mw7.8 earthquake is an ideal earthquake sequence on which to test our idea. It is unique in that it affected both crustal (shallow) and subduction (deep and shallow) faults, triggering widespread aftershocks, tremor, and slow earthquakes. We will present a time-dependent model of energy release throughout this sequence and compare it to models based on the Omori Law and discuss implications of this comparison on triggering and earthquake clusters.

Keywords: earthquake energy, Kaikoura Earthquake, back projection, aftershock, Omori, earthquake statistics