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Extracting scale dependent earthquake property time series and precursors with physical wavelets

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If magnitude M is sequenced in event order, it will show notorious irregularity, namely the unpredictable nature of M at any future EQ event. Thus, the acceptable assertion that earthquakes cannot be predicted would naturally seek for the firm ground in the Gutenberg-Richter relation (G-R) expressed in power-law [1]. The G-R states that the statistical property of random M is self-similar, which assures us of no scale to tell a future M at any EQ event. Namely, earthquakes are unpredictable. We note, the log-linear G-R has the self-similarity in a logarithmic relation of M to its energy, moment and rupture area.

The G-R is the cumulative frequency distribution; however, it would have filtered out any existing fluctuations [2]. Thus, only the G-R based unpredictability of EQ events will draw many objections to it [3]. One of the tenable objections to the assertion of unpredictable earthquakes is the multi-fractal nature found in the G-R for the de-clustered earthquakes, where only main shocks are selectively chosen [4]. Such scale dependent EQ events are also found at the ductile - brittle transition region (D-B) of the lithosphere, where the stress loading from the ductile to the brittle creates earthquakes with the characteristic magnitude Mc whose value takes about 3 or 4, depending on a regional seismic zone studied [5].

This physics-based unique scale Mc is very useful to separate the seismic activities below D-B from those in the brittle part. For example, an abrupt quiescence of regional EQ events with M GE Mc months before major earthquakes like the 1995 Kobe earthquake may be ascribed to an extremely large stress accumulation in the ductile part, which is yet to fracture the D-B and then a significant vertical portion of the brittle region right above it. The abrupt quiescence is one of the very subtle precursors masked with the random nature of EQ events, which we universally found in every recent major earthquake studied [6]. The precursory quiescence can be expressed with another well-known EQ property, inter earthquake time interval T that can also be extracted from Hi-Net.

Since the statistical nature of T free from aftershocks or the likes is random [7], one may again jump to the assurance that the time of any future EQ event is unpredictable beyond the probabilistic prediction. However, our autocorrelation analyses of T reveal many oscillations resonating with both tidal and unknown coupling forces, whose periods are in the order of minutes to months. The oscillations like our findings have also been reported elsewhere [8].

We have found these resonant oscillations on each sequence of EQ focus (latitude, longitude and depth) and M [6]. Since the scale dependent EQ events are tenable, we now view these events, EQ property time series, through the selective window (selective scale corresponding to each resonance), called physical wavelets [9], in order to gain the physical insight of EQ events. With the physical wavelets, we can find physics-based precursors, related to the abrupt quiescence discussed above, to large earthquakes (M GE 6 and depth LE 100km) in weeks or months ahead of time. Our short-term prognosis could also specify the local seismic region where the hypocenter will be located.

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