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Shortterm earthquake prediction with earthquake property time series and physical wavelets: An example of the 1995 Kobe earthquake

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Every earthquake (EQ) event in Japan is cataloged with its location (focus), time and magnitude [1]. Thus, the EQ events in any selective region can be sequenced in the event order with each EQ property; namely, latitude (LAT), longitude (LON), depth (DEP), inter-EQ time interval (INT) and magnitude (MAG). We denote each sequence by Da (a = LAT, LON, DEP, INT and MAG). The autocorrelation or spectral analysis of Da reveals many resonant oscillations masked with random fluctuations. Some oscillations appear to resonate with tidal force. Although others show no clear physical coupling mechanism, the resonant oscillations will ensure the scale-dependent EQ events, which means some scale-dependent precursors to large earthquakes may be found on the EQ property time series, Da [2].

We choose the Hiroshima area to find the scale-dependent precursors, because we have had eight major earthquakes with MAG GT 6 for the past 20 years. Three of them are MAG LE 7, including the January 17 1995 Kobe earthquake. We first extract Da with MAG ≥ 3.5 and 0 GT DEP LE 300 km for the Hiroshima area (32 GE LAT LE 36.5N, 132 GE LON LE 136E) from the JMA off-line catalog [1].

Intermediate term precursory activity is known to have local quiescence and increases in intermediate MAG activity [3]. For short-term precursors, we have found the same precursory activity on Da (a = DEP, INT and MAG) with physical wavelets [4]. The physical wavelets can selectively find each external force Fa to make Da resonate with the period of about 60 events. The Fa is almost free from random fluctuations and its 60-event period corresponds to about one year in the 1980s. During the precursory quiescence, Fa (a = DEP) will show the slow creep fractures in progress, concentrating around or above the ductile - brittle transition region that locates at DEP = about 20 km. Since our precursory quiescence oscillates with the same period of about 60 events, its phase information works as a warning clock to large earthquakes. We present an example of the precursor to the 1995 Kobe earthquake.

The very first clear sign to begin the quiescence had started around October 1993. It was then established during the period from May 8 of 1994 to September 8 of 1994. During this peak quiescence, we had 14 earthquakes on Da (a = MAG). Our precursory oscillation on each Da viewed with the physical wavelets gives us the physics-based dynamics of precursory force, Fa, to the January 17 rupture, while seeking for the possible hypocenter. The analysis of Fa (a = LAT, LON, DEP) also gives us physical insight to the crustal motion and creep fractures.

The outlook of our precursor was surprisingly in good agreement with the precursory chemical (chloride) changes found in grand water of Kobe [5] (see Fig.2 in [5]). The chlorine content was stable until September 1993. It started the oscillation of about 3-month period in November 1993, which might have coupled with tidal force. In early August 1994, the oscillation changed its period to reach the highest level previously established (before about 5 months). Then the level clearly reached another new peak, still oscillating. The steady increase in precursory chlorine content was finally established in October or November 1994. Another agreement with our precursory quiescence is the precursory chemical change of radon concentration found in ground water [6]. Some spikes on Fig. 2 in [6] are also attributed to the abrupt and short subtle quiescence extracted from Da (a = INT).

[1] JMA Catalog (Jan. 1983 to Sep. 2001)
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[3] Knopff, L., Proc. Natl. Acad. Sci. U.S.A., 93, 3830-3837 (1996)
[4] Takeda, F., JSME Inter. J. Ser. C. 37, No.3, 549-558 (1994). Takeda, F., Proc. 3rd Ex. Chaos Conf., World Scientific, 75-79 (1996)
[5] Tsunogai, U. & Wakita, H., Science 269, 61-63 (1995)
[6] Igarashi, G., et al., Science 269, 60-61 (1995)