Short-term earthquake prediction with GPS crustal displacement time series and Physical Wavelets: Tottori and Akinada earthquakes

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Daily displacement data of the crustal motion at a GPS site near a specified fault zone has three components in the WGS-84 coordinate system [1]. Each component is transformed into each geodesic component. Component x and y are those from S to N and from W to E, respectively. Component z is taken as altitude. Each displacement component, Da (a = x, y and z), is then sequenced in unit time (day) to form the time series of the crustal motion. A large earthquake (EQ) leaves a sudden large shift on Da right after the rupture with no visible precursor. The precursor appears to be completely masked with daily fluctuations of the local crustal motion.

However, if any creep fractures spread on the ductile-brittle transition region, the spreading will likely change the crustal motion. The kinetic energy KE of the crustal motion will then follow the change. The rate change of KE is the power PW that is proportional to the product of velocity V and acceleration A on the motion. Then any abrupt and large change of PW becomes the precursor to the abnormal creep fractures in the upper brittle region. We can find this precursory PW by comparing its magnitude with a predetermined critical level (threshold) of the PW [2].

The V and A, however, will have many frequency components of which only a few may show the creep fractures spreading abnormally. Thus, we use physical wavelets [2] to find the selective crustal motion coupled with tidal force. Among the annual, semi-annual, fortnightly and weekly coupling, we select the coupling of fortnight and week for A and V respectively, which are free from daily fluctuations. Using this precursory PW in our short-term prognosis, we have successfully found the precursory PW to all recent three major earthquakes in the Hiroshima area, the Chyugoku district.

They are; Western Tottori EQ (W-T) with magnitude 6.6 and depth 11 km (on October 6, 2000) [3], Northern Hyogo EQ swarm (N-H-S) with maximum magnitude 5.8 and depth 8 km (from January 12 to February 23 of 2001) [4] and the Akinada (Geiyo) EQ (A-K) with magnitude 6.8 and depth 50 km (on March 24, 2001) [5]. The precursory date to W-T, N-H-S and A-K are respectively 40, 24 and 37 days ahead of time. These findings are also in good agreement with the prognosis described in [6].

Some physical wavelets will give us a displacement-force phase relation on the crustal motion [2]. The trajectories drawn in the phase plane show some dynamic transition of the phases from normal to critical, whose transition will be also detected by precursory PW. The crustal motion at the two GPS sites for the Hyogo swarm and the Akinada earthquake, forming nearly identical phases until the Akinada rupture. This implies these two earthquakes are coupled by the motion of the subduction zone plate, which means the preceding shallow Hyogo swarm is a precursor to the deep Akinada EQ on the zone plate. It took 71 days to cross the zone plate to the Akinada EQ focus. We have found another coupling of an EQ swarm in the same Hyogo region with the August 7 1984 EQ of magnitude 7.1, which took 69 days to cross the same subduction zone. Thus, some swarms may be identified as a very reliable precursor to larger earthquakes in some districts [7].

If the current on-line GPS and earthquake catalog data are instantly available to the public, our physical-wavelet based earthquake prediction system may easily establish a forecasting system like those for typhoons and hurricanes at home [7].

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[4] NIED, http://argent.geo.bosai.go.jp/freesia/topics/hyogo/index.html (2001)
[5] NIED, http://argent.geo.bosai.go.jp/freesia/topics/akinada/index.html (2001)
[6] Takeda, F., submitted to the Joint Meeting of Earth and Planetary science (2002)
[7] Takeda, F., to be submitted.