The pre-slip controversy: a review of the 1944 Tonankai and the 2011 Tohoku-oki cases and their implications for short-term prediction

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In 2017, the Japanese government abolished a practical earthquake prediction of the so-called Tokai earthquake that started in 1978. A M8 class earthquake was supposed to be imminent in the Tokai area, the easternmost part of the Nankai Trough, based on the seismic gap hypothesis. The decision was based on recent scientific knowledge that reliable earthquake prediction is not possible for now.

An important scientific basis for the predictability of the anticipated Toaki earthquake was the tilt anomaly reported to occur just before the 1944 M8.1 Tonankai earthquake on December 7 (Sato, 1977; Mogi, 1984). This observation had been considered as a reliable precursory phenomenon by the Japanese scientists, but the IASPEI committee suspended their judgement to add this to the list of reliable earthquake precursors (Wyss and Dmowska, 1997). With a purpose of further investigation of this observation as an earthquake precursor, I revisited the whole original leveling field log by the survey team (from November 24 to December 25 of 1944) to examine if the reported tilt anomaly is reliable. Following three conclusions are obtained. (1) Two-way closure errors were reported anomalously large (over 3 mm for a ~700 m long section) only during a few days before the main shock. But the survey team had similar errors in other periods, which makes difficult to exclude a possibility of a simple measurement error. (2) One data in the morning of December 7 showed no significant change from 4 days before. The result does not necessarily indicate a single acceleration curve toward the main shock. (3) The coseismic uplift pattern along the leveling line prefers a fault motion shallower than the plate interface. This coseismic pattern should contain significant (more than 30%) contribution from precursory deformation. Another problem of this precursory anomaly was that the hypocenter of the 1944 Tonankai earthquake was located to the other end of the source region in the southwestern end. Linde and Sacks (2002) interpreted that a precursory slip might occur all along the source region below the main shock rupture. In conclusion, the reported tilt anomaly may be caused by pre-slip on the plate interface, as suggested by Kato and Hirasawa (1999). However, we must also admit that this observation is not strong enough for forcing people evacuate or limiting possesion rights to prepare for the emergency. It is impossible to reach a definite conclusion with available data.

Thus, another conclusion is that scientists should make an effort to investigate pre-slip phenomena based on data from modern equipment, which are much more precise and reliable.

The 2011 Tohoku-oki earthquake was a good example to test in that aspect. There have been several reports of aseismic slip and its acceleration based on repeating earthquake analysis as well as ocean bottom pressure gauges (Kato et al., 2012; Ito et al., 2013). Another interesting observation was a long-term trench-ward acceleration of crustal displacement in northeast Japan (Mavrommatis et al., 2014, 2015). In addition to the horizontal components they discussed, we reprocessed the GNSS data to improve quality of the vertical component and confirmed the accelerated subsidence along the Pacific coast of the Tohoku region. The accelerated subsidence and trench-ward motion suggest an acceleratied pre-slip or a loss of interplate coupling at the deeper end of the interplate locked zone. This result implies the precursory slip may occur on the plate interface as suggested by the numerical simulations based on the rate and state dependent friction law (e.g. Kato and Hirasawa, 1999). However, we still to not have a constraint on the time scale of such an acceleration for actual megathrust earthquake sources and how the time scale is variable from place to place. We conclude that we need to have more observational examples of precursory phenomena. And it should be noted that the actual spatio-temporal scale of such phenomena has not been well constrained so far. In that sense, making an observation-based forecast is still a true challenge and much efforts are needed before start practicing official forecast activities.

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