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Stress transfer in the Tokai subduction zone from the 2009 Suruga Bay earthquake in Japan

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1. Introduction

In southwest Japan, megathrust earthquakes occur at intervals of 100-200 years (Ando, 1975) at the subduction of the Philippine Sea (PHS) plate beneath the Eurasian plate. The M-8-class earthquake seismogenic zone is divided into three segments: Nankai, Tonankai and Tokai. Two megathrust earthquakes ruptured the Tonankai and Nankai segments in 1944 and 1946, respectively; however the Tokai segment did not rupture at that time and is still in a locked state. In 2009, an M_w6.4 earthquake took place in Suruga Bay, within the PHS plate, close to the Tokai segment. In this study we investigate the impact of the stress changes caused by the recent Suruga Bay earthquake on the Tokai segment.

2. Earthquake relocations and the rupture process of the Suruga Bay mainshock

The earthquake hypocenters of the Suruga Bay sequence (mainshock and aftershock activity) were precisely relocated by the double-difference method (Waldhauser and Ellsworth, 2000), using NIED’s Hi-net data. The relocation of earthquakes revealed a two-plane-shaped hypocentral distribution of aftershocks, indicating that the sequence occurred along two quasi-orthogonal faults, located in the southern (Fault I) and northern (Fault II) parts of the aftershock area. The mainshock hypocenter is located on Fault I.

On the basis of the two-plane fault model, we estimated the earthquake rupture process with a multi-time-window inversion scheme (Hartzell et al., 1983), using near-source strong-motion data from NIED’s K-NET and KiK-net stations. The results indicate that large slip areas extend around the connecting point of the two faults. Fault I, which ruptured first, was dominated by strike-slip, whereas Fault II underwent predominantly reverse faulting motion. So far there have been only a few reports of earthquakes rupturing two conjugate fault planes simultaneously (e.g., Robinson et al., 2001).

3. Stress transfer due to the 2009 Suruga Bay earthquake on the presumed Tokai fault plane

The slip model described above was used to calculate the static Coulomb stress change (ΔCFS) caused by the Suruga Bay event on the presumed Tokai fault area (Fig. 1). The “eggplant” shaped source region of the anticipated Tokai earthquake is based on the study of plate configuration and historical earthquake records. The rake at any given location in the source area was determined considering the plate motion direction. Stress change estimates are predominantly positive in inland regions northwest of the Suruga Bay hypocenter, exceeding 0.1 MPa up to ~8 km from the tip of the faults and gradually tapering off to ~0.03 MPa at ~15 km.

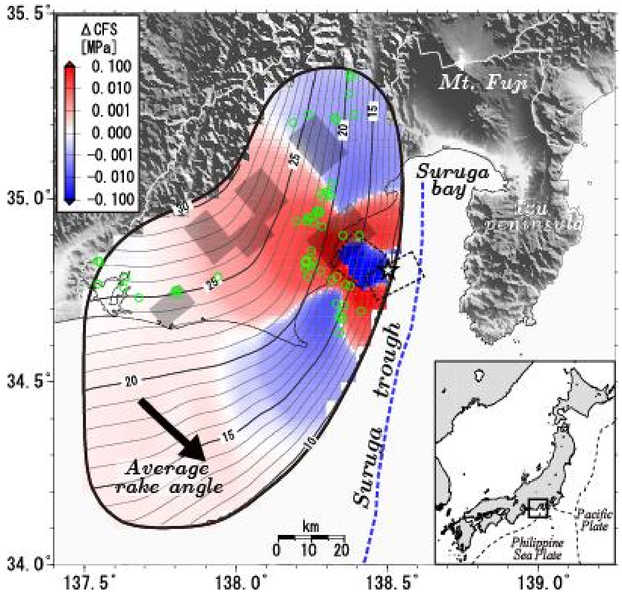

Fig. 1. Stress changes on the Tokai source area and earthquake triggering. The "eggplant" shaped source region is delimited by bold solid line. Positive and negative stress changes are shown in logarithmic scale. Contours indicate the depths of the plate boundary and the six gray hatched rectangles show presumed asperities. Green circles indicate interplate earthquakes that occurred on the Tokai source area, in the month after the Suruga-bay earthquake. Dotted rectangles show the conjugate faults of the Suruga-bay earthquake.

The analysis of seismicity, focal mechanisms and GPS data led Matsumura et al. (2008) to propose an asperity model for the anticipated Tokai event. The asperities – strongly locked patches at the plate boundary – are shown as grey-shadowed rectangles in Fig. 1. Five, in a total of six asperities, are situated in areas of increased stress, with the closest asperity having a ΔCFS significantly larger than 0.01 MPa. Stress increases (> 0.01 MPa) are potentially able to bring faults to failure with delays ranging from seconds to decades (e.g., Parsons et al., 2008).

To check for possible triggering at the plate interface by the 2009 Suruga Bay earthquake, we searched for events within location uncertainties from the Tokai source area, which occurred one month before to one after the Suruga mainshock. The events detected after the Suruga Bay earthquake are shown as green circles in Fig. 1. It can be noticed that most of them occurred in areas of positive ΔCFS. These events show also a clear Omori-type temporal decay. Moreover, well-resolved focal mechanisms for some of the detected events (M ~ 2.0) that occurred shortly after the Suruga Bay earthquake indicate thrust-type faulting. These observations strongly suggest earthquake triggering at the plate interface.

Conclusions

The precise relocation of the 2009 Suruga Bay aftershocks revealed a two-plane-shaped distribution. Using a two-plane fault model, we derived the slip on the Suruga Bay faults and calculated the stress changes on the source region of the anticipated Tokai earthquake. Our results show an increase of stress on most of the presumed Tokai asperities, with one of them experiencing significantly large ΔCFS values. Careful analyses suggest plate boundary micro-earthquake triggering by the 2009 Suruga Bay event.

Note: For a detailed analysis and discussion, we refer to:

Aoi, S., Enescu, B., Suzuki, W., Asano, Y., Obara, K., Kunugi, T. and K. Shiomi, Stress transfer in the Tokai subduction zone from the 2009 Suruga Bay earthquake in Japan, *Nature Geoscience*, 3, 496-500, doi:10.1038/ngeo885, 2010.