Static stress triggering investigation for the 2016 Kumamoto sequence

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[Overview] I study the static triggering of the Kumamoto earthquake (M_{JMA}7.3) by two successive foreshocks. I especially examine which of the two foreshocks mainly contributed to the triggering of the mainshock by evaluating the static Coulomb stress change (ΔCFS). I also discuss which fault model fits better the seismicity.

[Introduction] There are two large foreshocks before the Kumamoto mainshock: the first one (M_{JMA}6.5) occurred 2.5 hours before the second one (M_{JMA}6.4). The much larger mainshock (M_{JMA}7.3) occurred 25.5 hours later. I have calculated the static stress change due to the two foreshocks on the fault-plane of the mainshock to examine the triggering characteristics of the sequence. As it is well-known, ΔCFS shows whether slip on a fault (the "receiver") is encouraged or inhibited due to slip on another fault (the "source"). It is usually difficult to reliably determine the ΔCFS when the source and receiver faults are located nearby, since the stress estimation is sensitive to small variations of the fault-source slip distribution and its geometry. The hypocenters of the three events are within 10 km distance, so I assessed how much the estimated ΔCFSs depend on it.

[Comparison of fault models] I need reliable fault models for the two sources and the receiver. There are several fault models available for the Kumamoto earthquakes; for example, the fault models obtained by inversion of InSAR data, the P-wave polarity FM solutions and the CMT solutions. I consider such solutions as "fault models" because one can approximate the fault width and height from the magnitude. I designed a software tool that enables to compare seismicity and faults in 3D. Using this tool, the user can easily plot any earthquake catalog - for example, the MFT catalog of the Kumamoto sequence (Kato et al. 2016) or the JMA catalog –as well as any fault/slip model. I found that the seismic activity from the first foreshock until the mainshock is distributed along several planes. I compared the plane-like distributions to the fault models and found the CMT solutions of the foreshocks to better fit the seismicity than the InSAR models. Thus, I decided to adopt these solutions as faults and changed incrementally their parameters to examine the effect on the ΔCFSs.

[Triggering characteristics] The questions I try to answer are: (1) How much does the ΔCFS depend on the source slip distributions? (2) Which of the two foreshocks more likely triggered the mainshock?

[Method] (1) I assumed that the slipping source fault is represented by its CMT solution and it shapes as a disc (circular fault); I calculated ΔCFSs by changing incrementally the disc radius, as well as the dip and strike angles. The mechanism of the receiver fault (i.e., the mainshock fault) was that given by its FM solution. (2) I have done the same calculations for both source faults (i.e., for the two foreshocks).

[Results] (1) The ΔCFS depends less on the dip and radius of the slipping fault and more on its strike. This indicates that it is critically important to determine the strike angle accurately to evaluate the ΔCFS. (2) The ΔCFS due to the first foreshock was found to be more dependent on the radius of the disc (i.e., fault asperity). (3) The ΔCFSs due to the first foreshock were larger than for the second foreshock, thus suggesting that the first foreshock likely triggered the mainshock. I have further considered the circular asperity of the first foreshock to overlap with the largest slip distribution on the foreshock fault plane, obtained by Asano et al. (2016). By computing the ΔCFS for this asperity, I have obtained consistent large ΔCFS values that support our results.

[Conclusions]

(1) The first foreshock likely triggered the M_{JMA}7.3 Kumamoto mainshock, rather than the second one.

(2) It is important to determine strikes of faults with accuracy to calculate ΔCFS.

(3) The better fault parameters are those provided by the CMT solutions, rather than the InSAR fault model.

Keywords: seismicity, Kumamoto earthquake, fault model