InSAR ground displacements and slip distribution associated with secondary fault slips of the 2016 Kumamoto earthquake

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By using interferometric synthetic aperture radar (InSAR) and field reconnaissance surveys, activation of numerous secondary faults associated with the occurrence of the 2016 Kumamoto earthquake has been identified (e.g., Fujiwara et al., 2016, EPS). In this study, we investigated the characteristics of the displacements of secondary faults around the Miyaji district, Aso, within the Aso caldera, and further inverted for the slip distribution of the secondary faults.

In this study, we used RINC software (Ozawa et al., 2016, EPS) to produce three interferograms with different line-of-sight directions, and unwrapped with SNAPHU (Chen and Zebker, 2000). The unwrapped interferograms are "un-referenced", and each of them contains an unknown offset. The offset values were estimated using the daily coordinates data (F3 solution) of the GEONET network provided by the Geospatial Information Authority of Japan, and are subtracted from the interferograms. Finally, displacements along three line-of-sight directions are decomposed into EW, NS, and UD components, and EW and NS components were further used to derive the horizontal displacements in N50E direction, parallel to the secondary faults in Miyaji. The main characteristics of the ground displacements are as follows. (1) Two strands of parallel displacement discontinuity traces, corresponding to the surface fault, are observed, with a separation of around 0.8 km. (2) The length of the northern and southern strands of traces are around 1.3 km and 2.3 km. (3) Each of the two strands of traces are composed of multiple en-echelon traces. (4) The fault displacements of the northern strand were up to 5 cm for both vertical (northern side downward) and right-lateral directions. (5) The fault displacements of the southern strand were up to 8cm for vertical (northern side downward) and 10cm for right-lateral directions.

Next, we simultaneously estimated the slip distribution and geometry of the two faults (Fukushima et al., 2013, 2018), after removing long wavelength displacements by polynomial fitting. As for the fault geometry, we assumed that the top of the faults reach the averaged location of the fault strands and we set the dip angles as model parameters. We conducted non-negative least squares inversion for the fault slip, prohibiting reverse and left-lateral faulting based on the observed ground displacements. Two types of inversions were made on the assumption of the rake angle; one is assuming a uniform rake angle for all the fault elements, and the other is solving for the vertical and left-lateral slips. The two types of inversions both succeeded in explaining the ground displacement data, so we adopted the result of the simpler model with uniform rake angle as our preferred model.

In our preferred model, two faults dip northward with the southern one having a lower angle (48 degrees) than the northern one (67 degrees), making two faults merge at a depth of approximately 1.3 km. The lower limit of the slip area on the southern fault coincided the merging depth of 1.3 km, and the maximum slip of 25 cm was obtained at a depth of approximately 0.7 km. The slip on the northern fault was limited to shallower than 0.4 km with smaller slips of up to 12 cm.

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