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Assessment of Damage along Distributed Faults Using SAR Satellite Data

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Introduction

Disaster damage tends to concentrate in areas where surface ruptures and other forms of ground deformation occur. Accordingly, immediately after an event, it is essential to identify, from within the wide affected area, those surface deformation zones. In this study, using the 2016 Kumamoto Earthquake as the primary case example, we present instances of extracting coseismic surface deformation.

The Mw7.0 2016 Kumamoto earthquake occurred on the previously mapped Futagawa–Hinagu fault, in Japan. During this earthquake, many distributed surface ruptures appeared not only along the main fault but also away from the main fault(e.g., Fujiwara et al., 2016; Omata et al., 2016). We produced "low-coherence interferometric SAR" (LC-InSAR) images which contain both phase and coherence information of differential InSAR (DInSAR) analysis (Fig.1). We defined the line where phase discontinuity and low-coherence are confirmed, "phase discontinuity line" in this study. There are many "phase discontinuity lines" not only in areas where surface rupture was confirmed in post-earthquake survey, but also in areas where surface rupture was not confirmed.

Methods of LC-InSAR

There are two methods for extracting the faults using InSAR.

The first method is using the fringe images. By paying attention to the fringe discontinuity plane in DInSAR images, it is possible to extract ground deformities including faults. Since the fringe discontinuity surface includes local liquefaction and landslide etc., there is a possibility of extracting parts other than the faults.

The second method is using the coherence image. Paying attention to a region with low-coherence makes it possible to extract places with large surface deformation. However, since the region with low coherence includes landslide, seasonal variation, water area, etc., it is a problem that there is a possibility of extracting parts other than faults.

We combined DInSAR image, coherence images and slope images to make the LC-InSAR (Patent No. JP 6889993) (Fig.2).

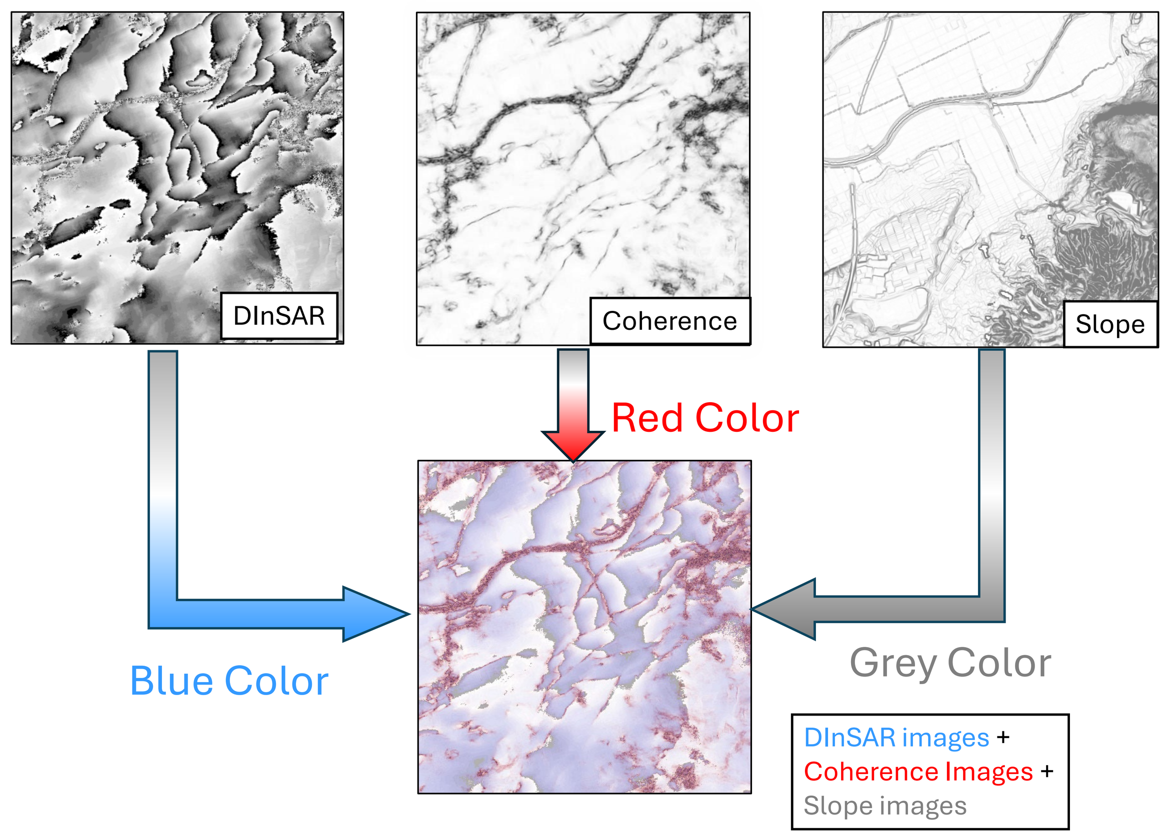


Fig.2 Image of LC-InSAR

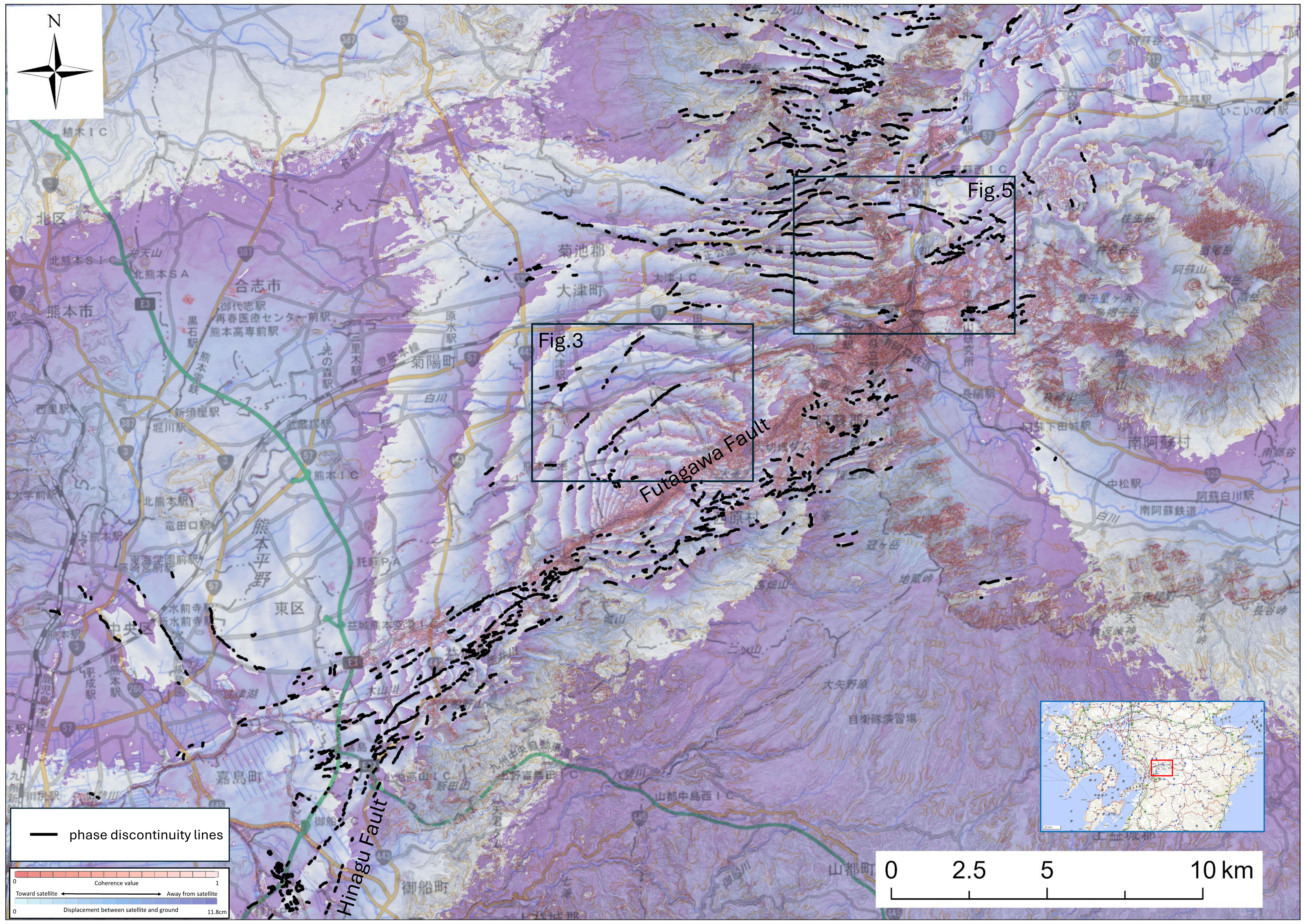


Fig.1 Image of LC-InSAR The 2016 Kumamoto earthquake (ALOS-2 DATA 2016/4/15－2016/4/29 Ascending Left)

Field Survey

We proposed the LC-InSAR map that simultaneously displays interferometric fringes and low-coherence derived from interferometric SAR analysis (Omata et al.,2016). In the LC-InSAR map, areas showing both phase discontinuities and low coherence values may indicate the presence of faults or surface displacement. We call these locations characterized by phase discontinuity and low coherence values phase discontinuity lines. Subsequent field investigations were conducted at sites distant from the main fault trace using the LC-InSAR images. These surveys revealed that where linear zones of phase discontinuity lines, either minute displacements had occurred or ground deformation was present that was too subtle to be readily identified as a surface rupture . At the Jin'nai site, a dextral displacement of the guardrail (approximately 20 cm) and cracks in the road were confirmed along the extension of the phase discontinuity line (Fig.3,4). At the Shimono site, a sinistral displacement of the road's center line (approximately 10 cm) and cracks in the road were confirmed along the phase discontinuity line (Fig.5,6). Both of these locations are far from the main fault of the 2016 Kumamoto earthquake. Minute deformation observed along these phase discontinuity lines was interpreted as being suggestive of distributed faults.

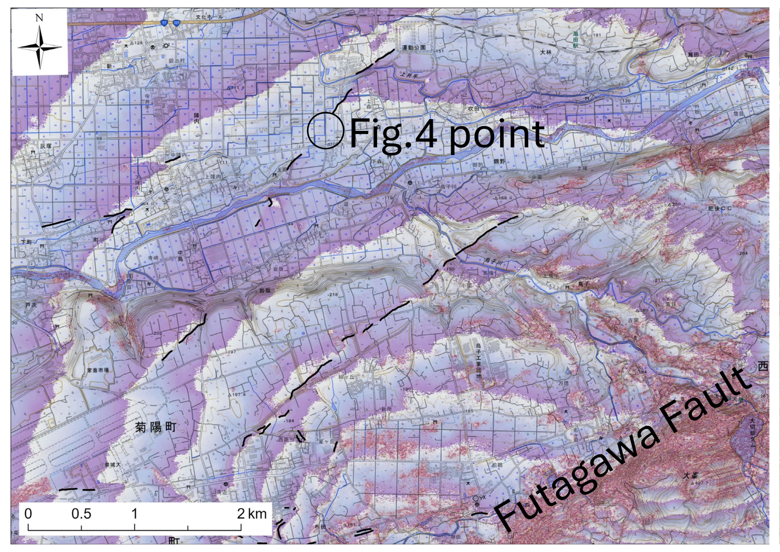


Fig.3 Map of the Jin'nai site

Fig.4 displacement of the guardrail

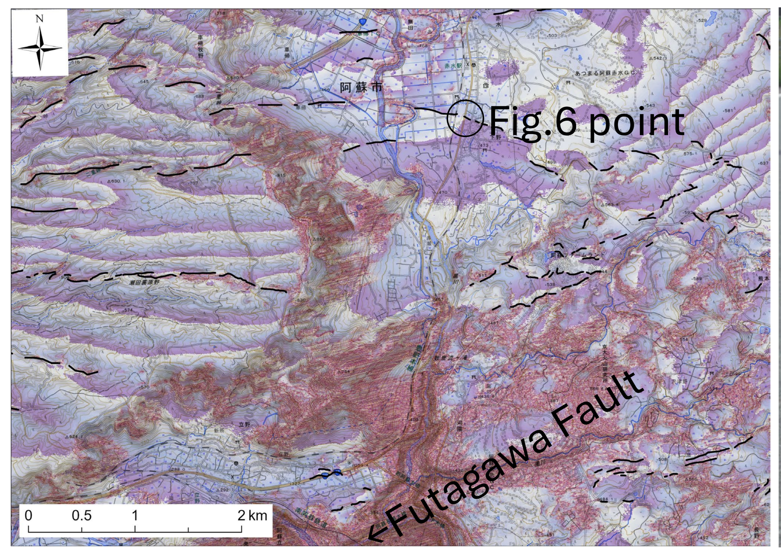


Fig.5 Map of the Shimono site

Fig.6 displacement of the road's center line

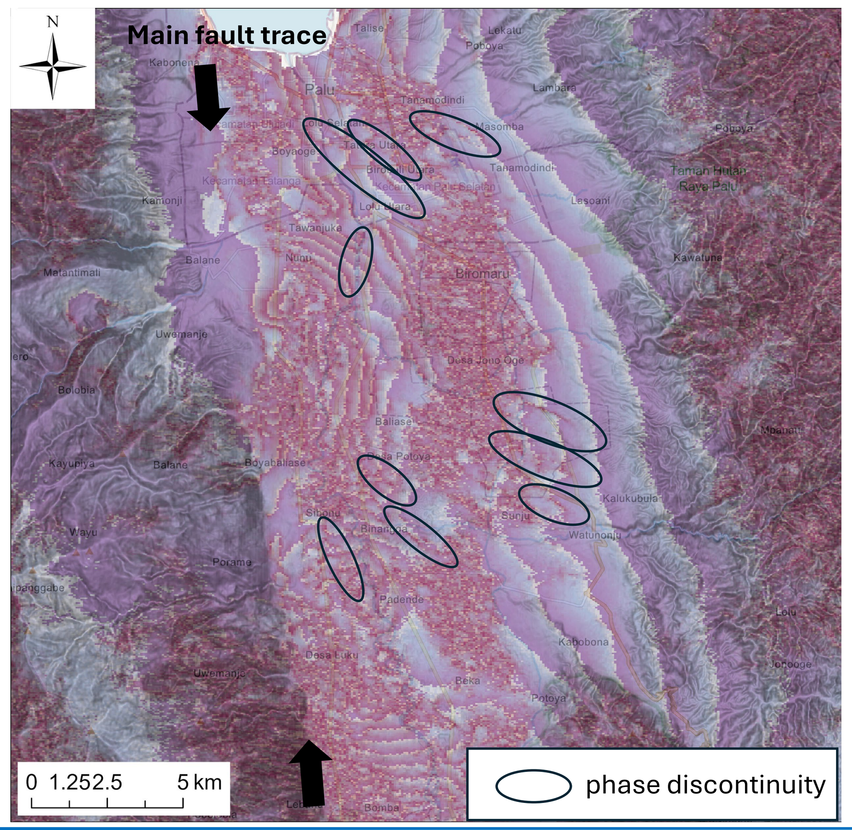
Surface deformation generated by distributed faults occurring at locations distant from the main fault trace should be regarded not as exceptional cases, but as phenomena that occur commonly during large earthquakes. Surface displacement along distributed faults has also been documented at sites far from the main fault trace, where such displacement has caused residential and infrastructure damage.

Conclusions

- Predicting the locations of these distributed faults in advance is extremely difficult.
- Analyses of SAR satellite data have revealed that damage can occur even along distributed fault traces that were previously considered unpredictable.
- **Although such information becomes available only after the occurrence of an earthquake, the use of satellite data enables the identification of damage related surface deformation zones across wide areas.**
- This, in turn, provides a basis for mitigating further damage during post-disaster response.

International Case Studies

Phase discontinuity lines occurring at locations distant from the main fault trace have also been documented in overseas earthquakes. Field investigations conducted after the 2019 Ridgecrest earthquake confirmed that ground deformation occurred along these phase discontinuity lines (Adachi et al., 2026).



In the 2018 Sulawesi earthquake in Indonesia, it was also recorded that phase discontinuities occurred at locations far from the main fault trace (Fig.7).

Fig.7 Image of LC-InSAR the 2018 Sulawesi earthquake in Indonesia (ALOS-2 DATA 2018/3/1－2018/10/25

Acknowledgment

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