

Nationwide crustal deformation mapping in Japan using L-band SAR data from ALOS-2 and ALOS-4

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Spatiotemporally comprehensive geodetic observations are often powerful tools for monitoring crustal deformation. Interferometric synthetic aperture radar (InSAR) is a promising technique for mapping ground surface changes at both regional and local scales. In particular, L-band InSAR, which has relatively low temporal degradation of coherence, allows significant deformation to be detected even in mountainous areas, making it well suited for monitoring the land surface of Japan, much of which is densely covered by vegetation. We, at GSI of Japan, have two primary missions related to the InSAR-based observations: one is to respond to natural disasters such as earthquakes, and the other is routine monitoring of ongoing ground deformation (Fig. 1). To achieve these objectives, we have processed over a decade of observations acquired by ALOS-2 satellite, equipped with an L-band sensor. ALOS-4, the successor to ALOS-2, was launched in 2024. Currently, the two satellites are operated as a virtual constellation, enhancing the capability for crustal deformation monitoring.

When a large earthquake occurs, we request emergency observations to Japanese space agency (JAXA) and process the data. The results are used not only for seismological studies but also official evaluation of seismic activities in government-related committees. The analysis results are provided to specialized conferences such as the Earthquake Research Committee, the Headquarters for Earthquake Research Promotion (HERP) for use in evaluation of seismic. In particular, SAR has contributed to evaluation of inland earthquakes. SAR has mapped crustal deformation with high spatial resolution, which has led to unveil detailed location and types of fault motions. A recent example of this is the response to the 2026 Kumamoto earthquake (Fig. 2), in which remarkable displacement discontinuities corresponding to right-lateral motion of active fault; Hinagu fault.

Another mission is a routine nationwide monitoring of ground deformation. InSAR time series analysis is an effective technique to improve the detectability of slow-progressing deformation by statistically processing a large number of InSAR images. The GSI has conducted the analysis routinely since 2021, and provided the results on GSI's online map. Our deformation map successfully detects various types of land deformations such as post-seismic deformation, deformation of volcanoes, and subsidence in which the ground has slowly deformed with a few mm per year. With the launch of ALOS-4, the observation frequency has increased from three to four times a year to 20 times a year, paving the way for high-frequency monitoring of spatiotemporal variations in deformation using the L-band.

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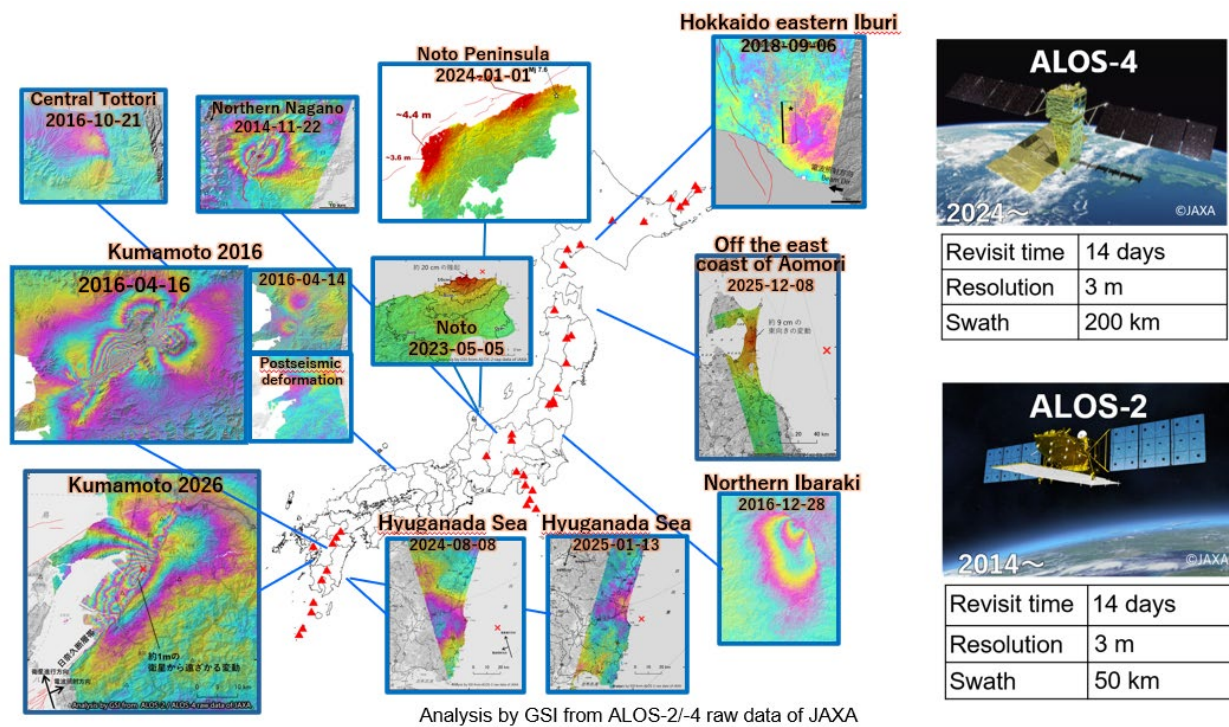


Fig. 1. SAR-based crustal deformation observation in response to large earthquakes in Japan.

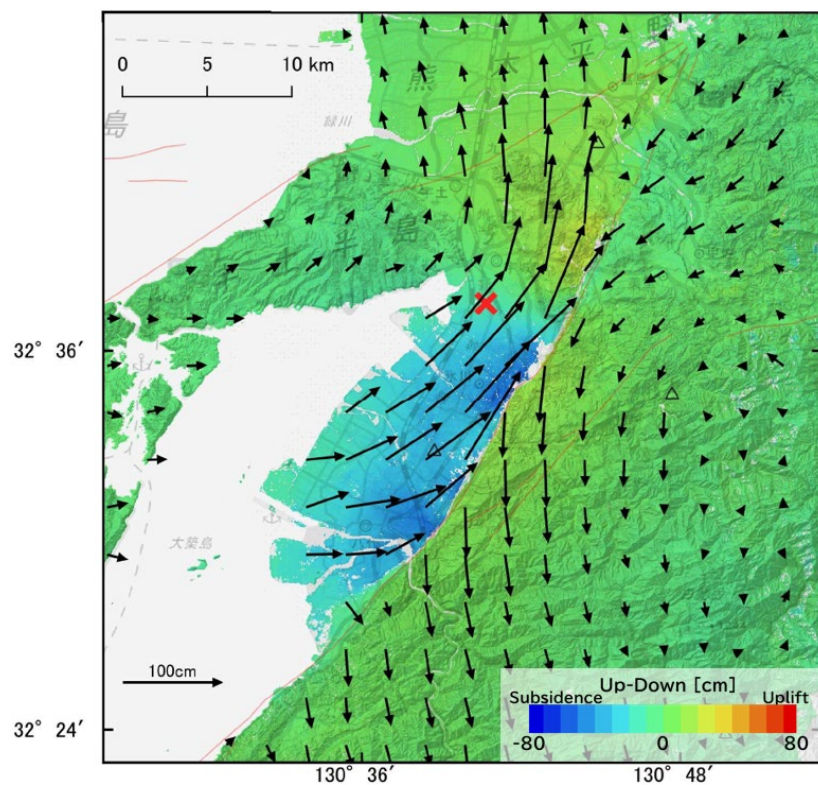


Fig. 2 Three-dimensional deformation map for the 28 July 2026 Kumamoto earthquake (Mw6.8) inferred from four-directional InSAR observations. Background color represents vertical displacement; warm and cool colors indicate upheaval and subsidence, respectively.