High-resolution 3D displacement field and stories behind: Studies in earthquake, volcano and underground nuclear test

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Synthetic aperture radar (SAR) imagery is a powerful remote sensing technology that allows for mapping the surface displacement with the resolution of a few meters. Although Interferometric SAR (InSAR) has been widely used in earth science studies, applications often suffer from decorrelation in the area of large displacement gradients, causing a data gap near the ruptured crust. Pixel offsets between SAR amplitude images can provide unambiguous ground displacement measurements in both the radar line-of-sight (range) direction and the along-track (azimuth) flight direction, allowing for deriving complete (3D) displacement in the near field. Here we will present how SAR amplitude images can help us to better understand geodynamic processes via three independent cases:

1) The 2014-15 Holuhraun fissure eruption at Bárðarbunga volcano, Iceland. In this case, we show the detailed time-series 3D deformation of a forming graben. We also show that the near-filed 3D displacement renewed our knowledge of how the crust opened during an oblique rift event.

2) The 2016 Kaikoura (New Zealand) earthquake. In this case, we combined SAR amplitude images from the ESA's Sentinal-1A and the JAXA's ALOS-2 for identifying surface ruptures and for deriving 3D coseismic displacements. We show that the vertical displacements are positively correlated with topography along the coast but are negatively correlated with topography farther inland, suggesting opposite coseismic contributions to the shaping of the Earth's surface in a single event.

3) The 2016 North Korea Nuclear test. In this case, we determined the first-ever 3D displacement field associated with an underground nuclear test using TerraSAR-X SAR amplitude images. Elastic dislocation modeling of the surface displacements and focal mechanism solutions consistently reveal compaction and collapse processes following the initial explosion.

The three cases presented here demonstrate that SAR amplitude information is important for revealing unprecedented displacement field near the ruptured crust. Such detailed geodetic measurements can bring new knowledge about the deformed crust.