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Editorial: InSAR crustal deformation monitoring, modeling and error analysis

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Editorial on the Research Topic
InSAR crustal deformation monitoring, modeling and error analysis

Background

Crustal deformation associated with endogenous forces of the earth (e.g., volcanic events, earthquakes, landslides, and collapses) and anthropogenic activities (e.g., urban construction, mining activities, oil and groundwater extraction) has been observed all over the world, which has become one of the most significant geological hazards globally. As one of the most effective means for measuring crustal deformation, interferometric synthetic aperture radar (InSAR) can provide high-resolution, high-precision, and large-scale land surface displacements as well as their spatio-temporal evolution behaviors. InSAR monitoring and modeling outputs can help understand the deformation mechanisms and minimize exposure of people and assets to potential damages. With the recent development and improvement in satellite technologies and extensive data computing methodologies, InSAR deformation monitoring, analyzing, and modeling, which is essential for disaster control, faces new and emerging challenges and produces remarkable progress.

Motivation for the topic

Over the past two decades, InSAR technology has become a powerful tool for measuring Earth's deformation with high spatial resolution and high precision and is playing a key role in monitoring various natural and anthropogenic hazards related to earthquakes, volcanoes, landslides, groundwater/oil extraction, urban construction, and mining activities, etc. Nowadays, many efficient InSAR approaches, such as PS-InSAR, SBAS-InSAR, DS-InSAR, etc., have widely been exploited over the years and have already demonstrated their values. With the recent development and improvement in satellite technologies and extensive data computing methodologies, it is time that we present some of the latest advances in InSAR Crustal Deformation Monitoring, Modeling and Error Analysis.

Summary of the papers

This Research Topic contains eleven articles published, involving sixty authors from seventeen research institutions. Most papers utilize mainly InSAR, D-InSAR, multi-temporal InSAR or multi-sensors InSAR techniques to investigate and analyze the ground deformation related to earthquakes, mining activities, landslides and extraction of groundwater, aiming to understand their dynamical mechanisms and provide technical support for assessment and early-warning of related geohazards. Some authors focus on developing novel methods to improve the reliability of deformation results. Deep learning approaches are also integrated within InSAR processing and recognizing deformation patterns. In the following, we summarize the main work and achievements of the papers.

Liao et al. combined D-InSAR and pixel offset tracking techniques to characterize the co-seismic displacement and extract the trace of the rupturing fault for the 2022 Qinghai Menyuan (China) Ms 6.9 earthquake. They inverted the slip distribution by adopting the steepest descent method and analyzed the stress condition of the surrounding faults based on the calculated Coulomb stress change. They suggested that attentions should be paid to Lenglongling fault, Tolaishan fault, SunanQilian fault, and Minyue-Damaying fault in future research. Li et al. obtained the co-seismic deformation fields of the 21 May 2021 Mw 6.1 earthquake in Yangbi (China) by use of Sentinel-1 SAR images acquired from ascending and descending tracks. The slip distribution of the rupture plane was inverted with the particle swarm optimization method. Results indicated that a steeply dipping dextral strike-slip fault controlled the earthquake. Wang et al. gave a detailed joint analysis of the co-seismic and post-seismic deformation of the 2020 Mw 6.0 Jiashi earthquake in Xinjiang (China) using both D-InSAR and SBAS-InSAR techniques. The optimal geometric parameters and slip distribution were inverted based on the Okada model. All papers above researched the deformation fields of recent earthquakes, aiming to provide useful information to better understand the tectonic background and mechanisms of corresponding regions.

Qin et al. jointly used the finite difference method 3D model and the stacking InSAR to monitor the ground deformation in the Fangezhuang coal mining area. By detailed investigation of the correlation between the spatial pattern of deformation and the geological faults, they concluded that the spatial extent of the observed ground movement was controlled by a tectonic fault that mining activities had reactivated. Not only ground surface of mining area is affected by considerable deformation, and the mine waste dump experiences subsidence which should not be ignored since it could cause landslides. Tabish et al. proposed a strategy to characterize and predict the spatio-temporal evolution of the subsidence of mine waste dump with the aid of InSAR and a secondary consolidation model. The method was applied and tested over a mine waste dump in Weijiamao mine (China). Low coherence induced by land use cover and deformation gradient is always a challenge for deformation monitoring in mining areas using InSAR. To overcome this limitation, Du et al. developed an improved phase optimization algorithm to increase the density of measurement points and reduce the influence of phase noise. It was demonstrated that the proposed method was practically feasible for long time and wide scale deformation monitoring in mining areas. Wang et al. presented a novel phase unwrapping method based on U-Net convolutional neural network to reduce the uncertainties resulted from inaccurate interferometric phase unwrapping. The method was compared with the traditional minimum cost flow method and its effectiveness was verified in Peibei mining area of Xuzhou, China. Yu et al. also integrated a deep learning algorithm (named Light YOLO-Basin model) but with different objective with Wang et al. The model was used to automatically recognize the subsidence basins in two typical mining areas with wide swath InSAR interferograms. It showed potentials in terms of detection speed and detection accuracy.

Identifying slope active deformation areas (SADAs) is important to early-warning and prevention of potential geological hazards. Wang et al. observed the long-term deformation in Zhouqu region (China) from January 2019 to February 2021 using DS-InSAR technique. They proposed a method for automatically identifying SADA based on the large-scale deformation results. It could effectively eliminate the region affected by geometric distortion. Zhu et al. focused on fully using multi-source, multi-sensor, and multi-temporal SAR images to detect ground deformation. With the help of spatial coherence estimated from Sentinel-1 interferograms, Ali et al. discriminated between active and stagnant dune regions, assisting in assessing aeolian activity in Bodélé Depression (Chad).

Future perspectives

The contributions of this research topic convey that InSAR has been a unique tool among the geoscience communities for making precise measurements of ground motions of various types. Distinguished authors have made rigorous and meticulous analyses of InSAR-derived deformation maps to reveal the geophysical fundamentals that underlie earthquakes, rock slides, ground subsidence, and underground mining activities. These have inspired us to explore more exciting technical and scientific breakthroughs in many aspects of InSAR. First, technological advances in InSAR will enable innovative applications where the usage of traditional InSAR is complex, such as recording glacier movements, flood coverages, fire scars, land cover types, and soil moisture contents. Second, nearly all studies in this special issue focus on using Sentinel-1 images owing to its availability and continuance.Nevertheless, other satellites with diverse signal wavelengths, polarizations, and orbit geometries offer more comprehensive deformation mapping capabilities, such as Sentinel-1C/D, Gaofen-3B/C, GeoSAR, and NISAR. Finally, automated InSAR processing systems will be more widely available such as the COMET-LiCS Sentinel-1 InSAR portal (https://comet.nerc.ac.uk/comet-lics-portal/), and Jet Propulsion Laboratory's (JPL's) ARIA Science Data System (https://asf.alaska.edu/data-sets/derived-data- sets/sentinel-1-interferograms/). These services provide rapid and continuous InSAR interferograms, which largely facilitate the routine monitoring of natural hazards and natural resources.

Author contributions

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Conflict of interest

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