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A Versatile Data Processing Package for Ground-Based Synthetic Aperture Radar Deformation Monitoring

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Abstract : Ground-based synthetic aperture radar (GBSAR) represents a powerful remote sensing tool for deformation monitoring towards various geohazards, e.g. landslides, mudflows, avalanches, infrastructure failures, and the subsidence of residential areas. Unlike spaceborne SAR with a fixed revisit period, GBSAR data can be acquired with an adjustable temporal resolution through either continuous or discontinuous operation. However, challenges arise from processing high temporal-resolution continuous GBSAR data, including the extreme cost of computational random-access-memory (RAM), the delay of displacement maps, and the loss of temporal evolution. Moreover, repositioning errors between discontinuous campaigns impede the accurate measurement of surface displacements. Therefore, a versatile package with two complete chains is developed in this study in order to process both continuous and discontinuous GBSAR data and address the aforementioned issues. The first chain is based on a small-baseline subset concept and it processes continuous GBSAR images unit by unit. Images within a window form a basic unit. By taking this strategy, the RAM requirement is reduced to only one unit of images and the chain can theoretically process an infinite number of images. The evolution of surface displacements can be detected as it keeps temporarily-coherent pixels which are present only in some certain units but not in the whole observation period. The chain supports real-time processing of the continuous data and the delay of creating displacement maps can be shortened without waiting for the entire dataset. The other chain aims to measure deformation between discontinuous campaigns. Temporal averaging is carried out on a stack of images in a single campaign in order to improve the signal-to-noise ratio of discontinuous data and minimise the loss of coherence. The temporal-averaged images are then processed by a particular interferometry procedure integrated with advanced interferometric SAR algorithms such as robust coherence estimation, non-local filtering, and selection of partially-coherent pixels. Experiments are conducted using both synthetic and real-world GBSAR data. Displacement time series at the level of a few sub-millimetres are achieved in several applications (e.g. a coastal cliff, a sand dune, a bridge, and a residential area), indicating the feasibility of the developed GBSAR data processing package for deformation monitoring of a wide range of scientific and practical applications.

Keywords : ground-based synthetic aperture radar, interferometry, small baseline subset algorithm, deformation monitoring
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