Exploitation of a Multi-Grid Differential SAR Interferometry (DInSAR) Approach for the Investigation of Large-Scale Earth’s Surface Deformation: Experiments on the Pearl River Delta (PRD) Region

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Abstract

In this study, we show the potential of an adaptive quadtree-based data decomposition method [1], [2] applied to Differential Synthetic Aperture Radar (DInSAR) data. Specifically, the proposed method exploits a multi-resolution scheme for the phase unwrapping of sequences of differential SAR (DInSAR) interferograms and allows one to produce SAR deformation products at different scales of resolution. The selection of the used multi-grid is based on the analysis of the statistical properties of a sequence of interferometric phases. It allows recognizing major deformation areas where phase unwrapping operations can be performed more efficiently, with a computational improvement and without losing any significant information.

Introduction

DInSAR [3] is a well established technique that allows a timely monitoring of Earth’s surface displacement phenomena with a dense grids of measurement points. The availability of measurements over dense spatial grid represents the typifying factor of the DInSAR technology with respect to other conventional approaches (e.g., GPS and levelling measurement campaigns). However, in regions where the density of coherent points is large, the use of dense grid of measurement points leads DInSAR being not very efficient from the computational point of view, even more when we want to investigate the temporal evolution of the detected deformation phenomena [4]. This is done through the inversion of an appropriate set of interferograms produced from a sequence of temporally separated SAR acquisition of the examined area. In this latter case, the major computational load in the displacement time-series process is associated with the phase unwrapping step (see Figure 1).

Objective

The goal of this study is to prove that, at least in correspondence to the highly coherent targets on the ground, the deformation signals can be detected at different scales of resolution [5] using local adaptive multilook factor (e.g., 2x10, 4x20, 8x40, etc...) by optimizing the computation time and preserving details of deformation as much as possible. The area of interest is the Pearl River Delta area, specifically the island of Hong Kong (Figure 2) that is characterized by subsidence phenomena.

Methods

We present a statistical multigrid decomposition algorithm to compute the mask of coherent pixels where to perform the phase unwrapping (PHU) operations. They are relative to major deformation areas at different scales of resolution (see Figure 3). The method is described by the following pseudocode, which refers to a single starting point and uses a scale factor between two neighbor resolution scale of ¼, so one pixel at coarser grid corresponds to four pixels at next higher resolution scale (see Figure 3). A stack of N DInSAR interferograms is considered, the spatial high-pass phase components at every pixel at a given resolution scale is calculated. The variance [6] of the high-pass phases is used to identify those pixels where to efficiently perform PHU operations.

Results

The presented analysis relies on a set of 60 SAR data acquired by the Sentinel 1A/1B radar sensor over the island of Hong Kong from December 2017 to January 2019. Starting from these data, we generated a stack of 226 interferograms at three different resolution scale, 2x10, 4x20, 8x40 on which we have tested the adaptive quadtree decomposition method and subsequently compute at 2x10 scale the time-series deformation and the mean deformation velocity map (see Figure 5).

Discussion

From the deformation time series and the mean deformation velocity map computed at scale 2x10, we focused on three-man-made lands reclaimed from the sea that are major characterized by subsidence phenomena which: Hong Kong airport (Figure 5a), Hong Kong Disneyland (Figure 5b) and Hong Kong city coast area (Figure 5c). These results have been produced with an improvement in terms of data reduction of about 85% for every scale for the PHU operation (Figure 6). Coherent areas have been pre-selected at the 8x40 scale.

Conclusions

We have presented a DInSAR method to recognize and efficiently process a sequence of DInSAR interferograms and retrieve the deformation signals at different scales of resolution, with a high improvement in terms of performances of the involved phase unwrapping operation. Additional analyses are needed to confirm the validity of the method, i.e. using more than three resolution scales, testing the method in areas affected by different deformation phenomena, efficiently identifying the sets of pixels at the lowest scale of resolution.

References