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Comparison of Multi-Temporal Differential Interferometry Techniques Applied to the Measurement of Bucharest City Subsidence

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Abstract

This paper aims to present some of the most popular multi-temporal differential interferometry (DInSAR) techniques that are used for monitoring surface deformations in different types of areas. We focus on the urban area of Bucharest, where we applied the PS (Persistent Scatterers) and SBAS (Small BAseline Subset) techniques. The PS approach analyzes interferograms generated with a common master image, looking at point targets that remain stable over time, generating signal that remains coherent from an acquisition to another. The SBAS approach relies on small baseline interferograms that maximize the spatial and temporal coherence. In this paper we compare these techniques by applying them to the urban area of Bucharest using TSX data. . Both PS and SBAS methods generate millimetre ground displacement rates. The PS subsidence values range from -22 mm/yr to 22 mm/yr while the SBAS value rates are lower, from -10 mm/yr to 10 mm/yr. The subsidence rate maps are compared from a quantitative and qualitative point of view, taking into account also the type of movements that the techniques can derive. The current paper is mainly methodological oriented, aiming to present the PS and SBAS techniques in a comparative way. Less emphasis is put on the initial results, which are presented briefly in order to give an insight about further study directions.

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Keywords: DInSAR; PS, SBAS, subsidence

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1. Introduction

Due to its capacity to provide extensive and up-to-date geospatial information, remote sensing becoming an important technology for natural hazards management. Data fusions between optical, radar and thermal imagery can play a role in each of the four phases of disaster management cycle (mitigation, preparedness, response and recovery) [1] for hazards like earthquakes, volcanic eruptions, flooding or landslides. Optical, thermal and microwave data have been used for detection of earthquakes and faulting, [2, 3, 4], volcanic activity [5, 6, 7, 8, 9], landslides [10, 11, 12, 13] and flooding [14, 15, 16].

Ground subsidence represents another type of hazard that is evolving during a large time scale, being characterized by smaller but consistent changes. Ground subsidence manifests more frequently in urban and peri-urban areas, being triggered various causes such as water exploitation or mining [17]. The subsidence rate in urban areas can influence the flooding risk and cause infrastructure damages through ground fractures [18]. Therefore, we consider that subsidence is a phenomenon that should receive the same importance as the other mentioned hazards. Most important application of remote sensing for urban environments is assessing the extent of damages suffered by an area affected by hazards, and monitoring its recovery. In urban areas the damage assessment is done by interpreting the degree of building damage, flood levels or ground movements in case of earthquakes and landslides. The downside of using optical imagery for damage assessment in urban zones is that the affected areas are identified mainly through manual interpretation [19, 20]. This type of application depends on user's experience and can be subject of interpretation errors.

A faster and more accurate detection of the affected infrastructure or ground motions due to hazards would require a change in spectral reflectance that can be depicted automatically. But in most cases, changes that affect the buildings structure cannot be identified by means of spectral information. Better results were obtained by Stramondo et al., (2006)[3] through image differencing of multi-date spectral ratios of multi-temporal optical and Synthetic Aperture Radar (SAR) imagery to detect building debris after earthquakes in Iran and Turkey. SAR data can be used to measure changes in topography and building damages through multi-temporal analysis of pre and post disaster imagery [21]. However this technique is limited by the significant variance of the backscatter intensity of different areas and dependence on incidence angle [1].

When it comes to mapping ground deformations, Differential SAR interferometry is considered one of the best available techniques. DInSAR calculates the phase difference between images acquired at different times, before and after an event [22, 23]. Phase difference is an indicator of the degree of change suffered by an area between two acquisitions. Phase decorrelation can be caused by different surface condition between two acquisitions, different atmospheric conditions or large spatial baselines. The accuracy of this technique depends therefore on many parameters, like ground and atmospheric conditions, wave-band and backscatter intensity. With an accuracy better than a quarter of SAR wavelength, the techniques is suitable for mapping ground deformations caused by moderate earthquakes and landslides, or identifying building debris and large displacements through decorrelation between acquisitions.

Considering all possible parameters that can influence phase changes between acquisitions, and the small order of magnitude for displacement values, the aim of this paper is to investigate how two different multi-temporal DInSAR techniques can emphasize complementary data about Bucharest study area. The two techniques that we apply are Permanent Scatterer and Small BAseline Subset interferomtery.

The test area is Bucharest, the capital of Romania and the largest city from the country with a population of approximately 2 million inhabitants. Bucharest is found in the South-Eastern part of the country, the Bucharest area is located in the Romanian Plain between the Carpathian Mountains in the North and the Danube River in the South, on the foreland basin of the Carpathian Mountains. The near-surface geology is represented by up to 300 m thick layering of Quaternary poorly-consolidated fluvial and lacustrine deposits. The plain landscape was shaped through fluvial processes determined by two small rivers: the Dâmboviţa, and its left side affluent, Colentina.

Main hazards affecting Bucharest's area are earthquakes and subsidence. Ground subsidence values are not critical, but they may influence the seismic response of the urban area. Bucharest's area is also characterized by a weak intensity of signal backscatter, indicating low rates of displacements.

In the following sections we present a comparison between the mentioned techniques regarding principles and data processing steps, and a short insight on our initial results obtained for a dataset of TSX images covering