NEWSLETTER 2
FEBRUARY 2021

# SCIENCE

**SCIENCE:**
**SpaCeborne SAR Interferometry as a Non-invasive tool to assess the vulnerability over Cultural hEritage sites**

## CASE STUDY: NANJING CITY WALLS, CHINA

**Taking the cultural heritage of Nanjing Ming City Wall (Fig.1) and its 200-meter buffer zone as an example, we conducted a comparative study of deformation calculation and performance assessment between the current PSInSAR and the sequential PSInSAR method based on the optimized search-space using 32 scenes of Cosmo SkyMed stripmap images (in descending orbits) acquired from January 2015 to February 2018.**

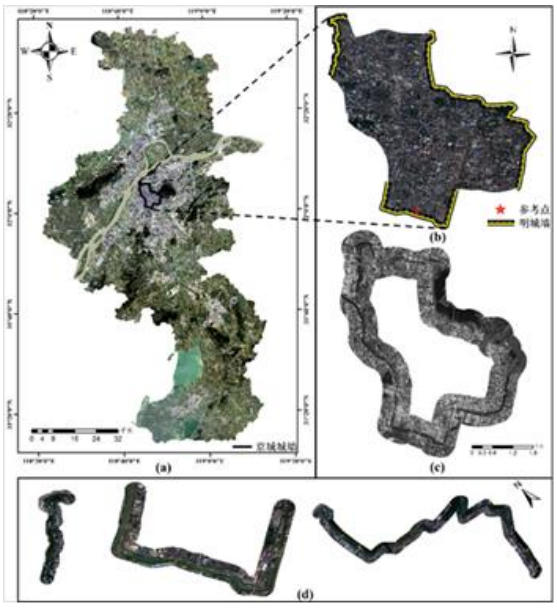


**Figure 1.** Overview of the study area. (a) The location of Nanjing Ming Dynasty City Walls with the "capital city wall" highlighted by the black polygon, (b) the remains of city wall on the GF-2 imagery, (c) SAR image of "capital city wall" with its region of interest for processing, and (d) three selected sections of heritage walls.

## THE METHOD

**Facing the limitation of the current flow of persistent scatterer SAR interferometry (PSInSAR), we proposed a sequential PSInSAR algorithm based on optimized searching-space. It achieves a seamless embedding of new SAR images in order to avoid the repeated entire data processing flow of the current PSInSAR tools and realizes a quasi-real-time update of deformation parameters by the induced technical improvement in the differential SAR interferometry (DInSAR) processing and the subsequent deformation time series inversion.**

## RESULTS

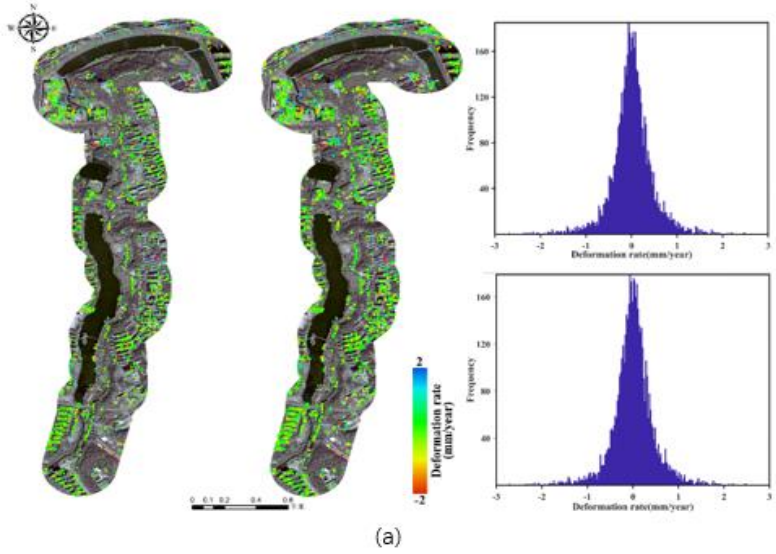
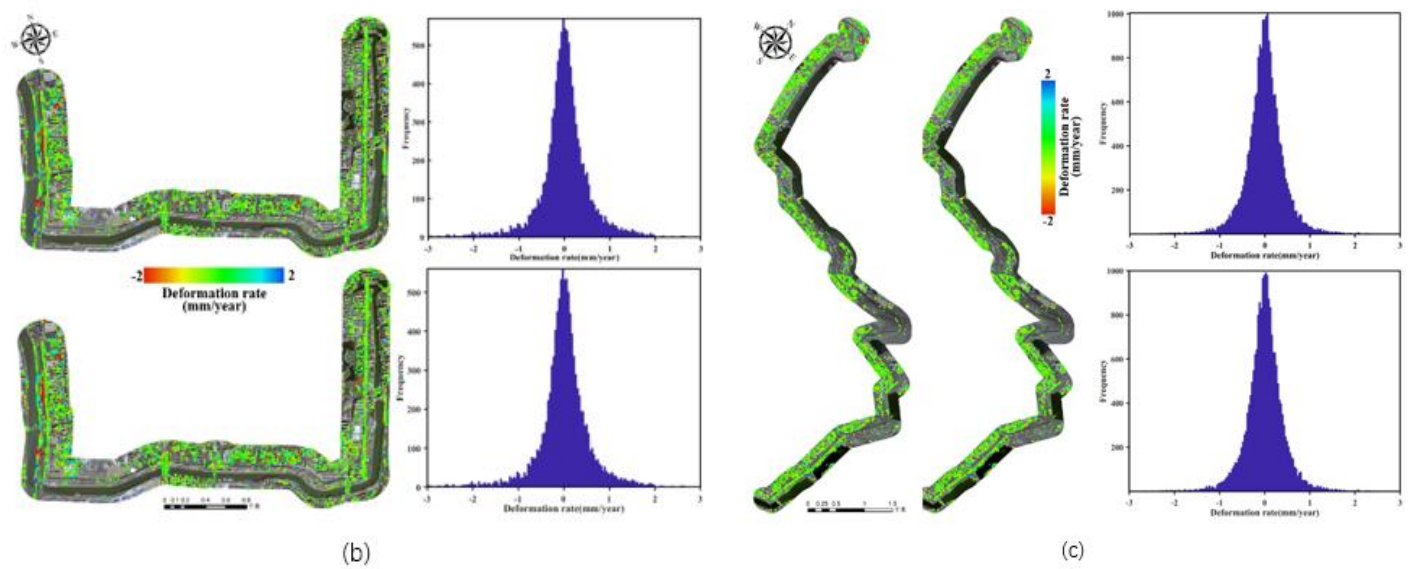



**Figure 2.** The comparison of the estimated deformations between the PSInSAR and sequential PSInSAR approach along the (a) Shizishan-Dinghuaimen section of Nanjing City walls.

# RESULTS




(b) Xishuiguan-Dongshuiguan and (c) Yueyahu park-Shencemen sections of Nanjing City walls.

**The results show that the sequential PSInSAR (Fig.2) based on the optimized searching-space simplifies the process of DInSAR and achieves a reduced calculation consumption with approximately an order of 10 times by the improved searching mechanism and the resultant reduced calculation complexity of unknown parameters. The cross comparison of deformations (Fig.3) from aforementioned approaches indicated a consistent result (the overall dispersion within 0-1 mm), validating the effectiveness and reliability of sequential PSInSAR method proposed. This study reveals the application potential of the sequential PSInSAR approach in the accurate, quasi-real-time deformation monitoring of cultural heritage in the era of remote sensing big data.**

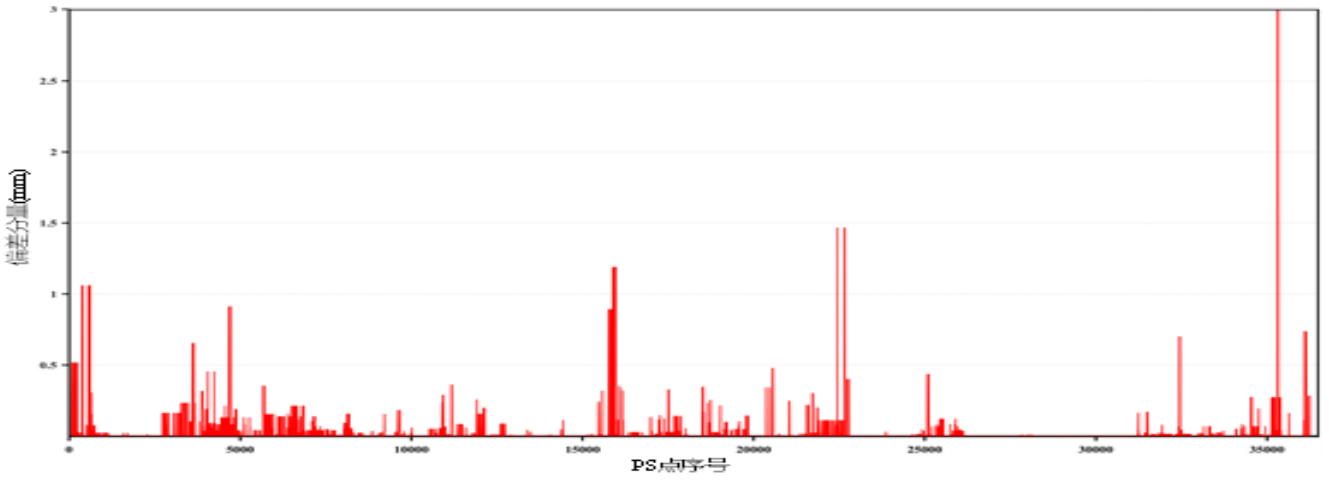



**Figure 3**. Deformation deviations of two methods on PS points.

# CASE STUDY: THE ACROPOLIS COMPLEX OF ATHENS, GREECE

**In the framework of the Acropolis complex of Athens case study a variety of Persistent Scatterers are combined aiming to produce highly accurate deformation maps (Persistent Scatterers Interferometry - PSInSAR) for the prediction of the vulnerability of the ancient monuments (Parthenon, Propylaea e.t.c) to ground deformation in time and space.**

**The dataset that has been utilized is consisted by 274 Single Look Complex (SLC) images acquired by the Copernicus Sentinel-1 satellites in ascending orbit for the time period from October 2014 to May 2020.**

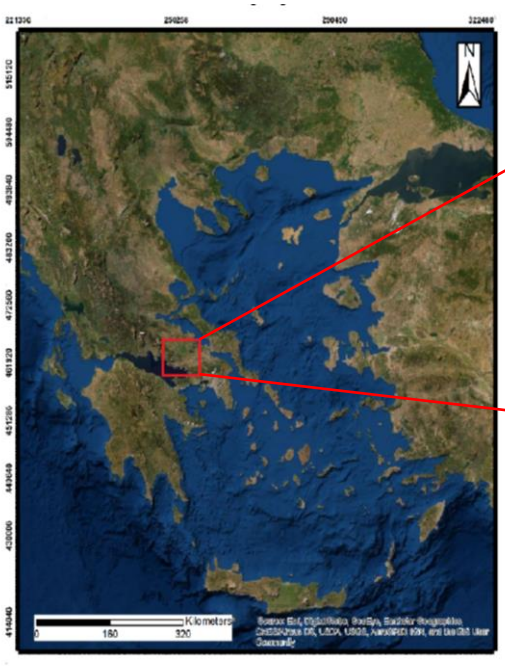



**Figure 4.** Location map of the Acropolis of Athens in Greece (red square).

**The Acropolis Complex is located (Fig. 4) in the center of the city of Athens and from a geological point of view lies upon two lithostratigraphic units of the Athens schist (upper Cretaceous) and the overlying Acropolis limestone (upper Jurassic).**

## THE METHOD

**PSI technique (Interferometric Point Target Analysis - IPTA algorithm) is applied to the first Greek case study of Acropolis complex of Athens. The datasets are processed in GAMMA software. The main characteristic of the IPTA algorithm is that the interferometric analysis is possible for chosen point targets with a particular range and azimuth. Specifically, PSI assumes the presence of a single temporally coherent scatterer in a range-azimuth pixel with multiple scatterers interfering in the same pixel, as for the case of a layover to be typically rejected. This is one of the main limitations of PSI that SAR tomography has the potential to overcome and retrieve the elevation and deformation parameters for multiple scatterers in the same resolution cell.**

## RESULTS

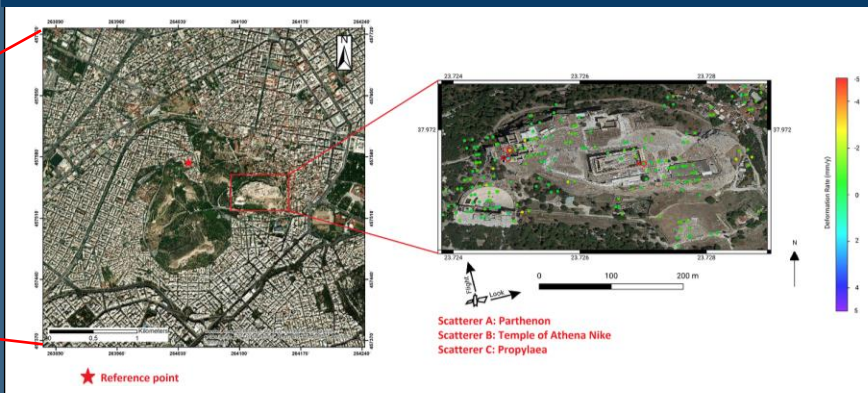



**Figure 5.** The area that the Acropolis of Athens is located with the reference point of PSI technique (red star) and zoom-in (red square) to the persistent scatterers for each one of the ancient monuments. A, B and C are the selected scatterers.

**In Fig.5 are presented the PSI results for the Acropolis of Athens. Below are presented the multitemporal deformation diagrams.**

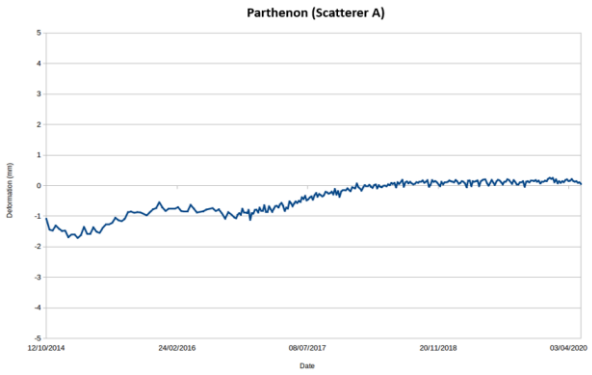



**Diagram 1:** presents the multitemporal deformation of Scatterer A (Fig.5) of Parthenon monument.

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# RESULTS

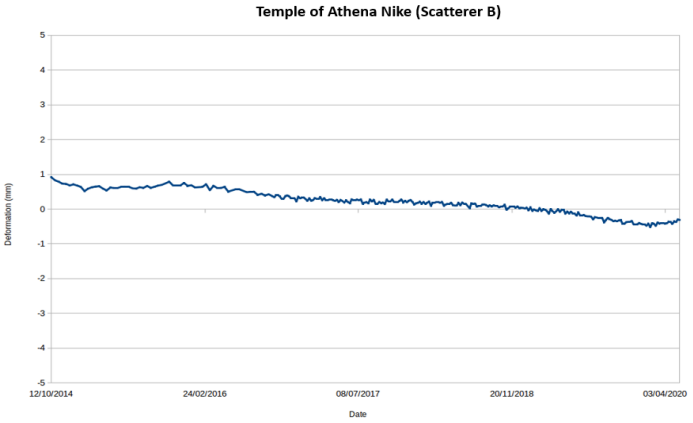


**Diagram 2:** presents the multitemporal deformation of Scatterer B (Fig.5) of Temple of Athena Nike monument.

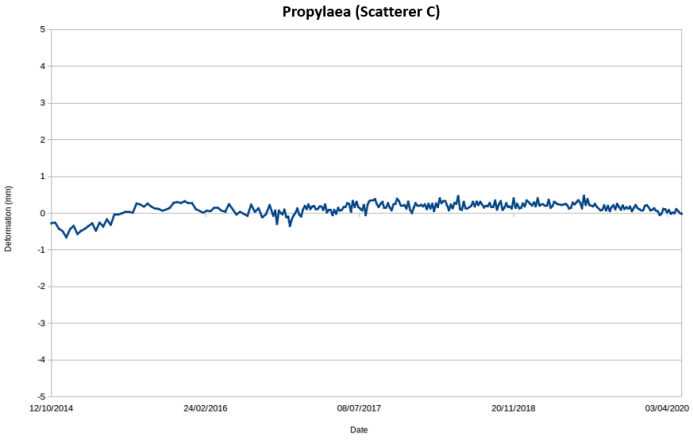


**Diagram 3:** presents the multitemporal deformation of Scatterer C (Fig.5) of Propylaea monument.

**According to Diagrams 1,2 and 3 corresponding to the monuments of Parthenon (Scatterer A), Temple of Athena Nike (Scatterer B) and Propylaea (Scatterer C) respectively, is presented the movement of the selected scatterers along the Line-Of-Site (LOS).**

**In particular, the negative values in the presented multitemporal diagrams corresponded to the movement of the scatterer away from the LOS of the satellite and the positive ones corresponded to the movement of the scatterer towards the satellite.**

**As it can be shown comparing the three selected scatterers: Scatterer C (located to Propylaea) showed stability during the time-period of October 2014 to May 2020 compared to Scatterer A and B, which showed variations to their movement across the LOS.**

**Moreover, Scatterer A (located to Parthenon) seems to move towards the LOS of Sentinel-1 in comparison to Scatterer B (located to the Temple of Athena Nike), which seems to move away from the LOS of Sentinel-1.**

**The factors that could affect the multitemporal deformation pattern of the scatterers are related to the geological background of the area (karst limestones, exfoliated schists, erosion phenomena) and the climate change (heavy rainfalls, thermal dilatation).**

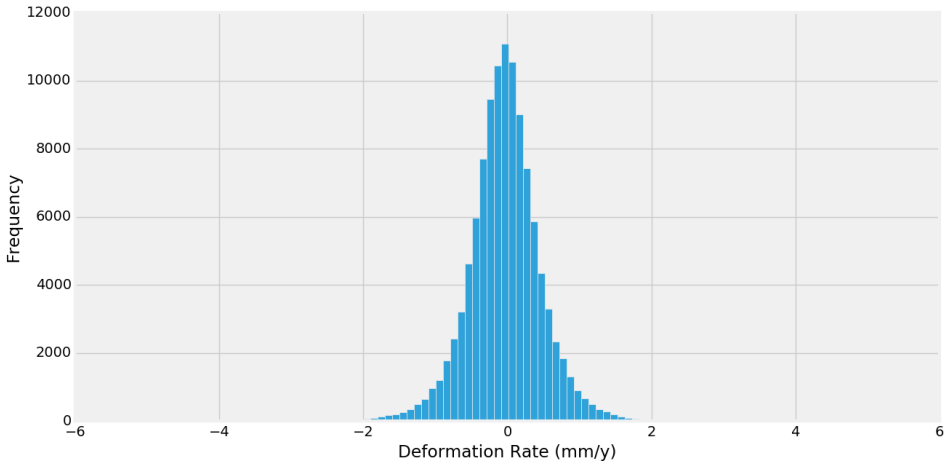


**Figure 6.** The estimated deformations of PSInSAR approach along the Acropolis Complex of Athens in Greece.

## RELATED PUBLICATIONS


Chen F., Zhou W., Xu H., Parcharidis I., Lin H., Fang C., (2020) Space technology facilitates the preventive monitoring and preservation of the Great Wall of the Ming Dynasty: a comparative study of the Qingtongxia and Zhangjiakou sections in China, in **IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing**, doi: 10.1109/ JSTARS.2020. 3023297 (IF = 3.8).

Xu H., Chen F., Zhou W., Zheng W., Deng Y., Parcharidis I., (2020). Three-Dimensional Deformation Monitoring and Simulations for the Preventive Conservation of Architectural Heritage: A Case Study of the Angkor Wat Temple, Cambodia. **GIScience & Remote Sensing**, (accepted in press), doi: 10.1080/15481603.2020.1871188 (IF = 5.9).

Tompolidi A., Fylaktos A., Gatsios Th., Parcharidis I., (2020). SCIENCE PROJECT: SpaCeborne SAR Interferometry as a Non-invasive tool to assess the vulnerability over Cultural hEritage sites. In Proc. **Safe Greece2020** - 7th International Conference of "New Technologies and Civil Protection.14-16 October 2020.


## UPCOMING EVENT

**Virtual presentation of SCIENCE project in EGU General Assembly 2021. 19-30 April 2021 in Session NH6.8. Remote Sensing and Cultural Heritage.**

Tompolidi A.**,** Parcharidis I., Loupasakis C., Fragkiadakis M., Soupios P., Grigorakou E., Achmet Z., Kalousi G., Eleutheriou V., Christodoulopoulou R., Michalopoulou D., Kanaki E., Mavromati D., Sythiakaki V., Elias P., Gatsios T., (2021). SpaCeborne SAR Interferometry as a Nonivasive tool to assess the vulnerability over Cultural hEritage sites (SCIENCE). In Proc. **EGU General Assembly 2021**. 19-30 April 2021 (accepted).

## PROJECT COORDINATORS – PRINCIPAL INVESTIGATORS


Chinese part
CHEN Fulong, Dr. & Professor
Aerospace Information Research Institute, Chinese Academy of Sciences

Greek part
Issaak Parcharidis, Professor
Department of Geography, Harokopio University of Athens



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