Exploitation of Copernicus satellite data for monitoring fishing shelters in Cyprus using advanced InSAR techniques: The case study of Agios Georgios Pegeias fishing shelter in Paphos, Cyprus

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ABSTRACT

Fishing shelters are among the critical infrastructures that necessitate continuous monitoring to ensure their functionality and safety in Cyprus. Currently, Cyprus hosts sixteen (16) operational fishing shelters, covering the coastline. In the last few decades, Advanced Interferometric SAR techniques have been the most effective methods for concurrent monitoring critical infrastructures. The current study investigates the potential of the A-InSAR techniques to identify displacements of the fishing shelters in Cyprus. Following various discussion with the relevant stakeholders, the Agios Georgios Pegeias fishing shelter in Paphos was selected as the pilot study for further investigation. The satellite dataset consists of 148 Copernicus Sentinel-1A in descending mode, covering a time span of 2019-2023, achieving comprehensive and cost-free monitoring. The PSI technique was carried out using the freely available snap2stamps and StaMPS toolboxes, as well as the Matlab and ArcGIS Pro commercial software. The results of this study presented a slight displacement of about -5 mm/year at the edge of the fishing shelter, while the broader area remains stable. The displacement rates are referred to the LoS and they are visualized in GIS environment.

Keywords: InSAR, fishing shelters, Sentinel-1, Cyprus, disaster risk reduction

1. INTRODUCTION

Fishing shelters serve as critical infrastructures, providing safe harboring and mooring for professional fishing vessels. Also, in every fishing shelter there are slipways that are open to the public and free of charge. Currently, there are sixteen (16) operational fishing shelters in Cyprus, covering the coastal zone of the island, as depicted in Figure *1*. The continuous improvement works that are made on a constant basis, provide safety and cover the needs of each fishing shelter, on a buffer zone of 100m around each fishing shelter[1]. The need for continuously monitoring these infrastructures is essential, ensuring their safety and effective use. Advanced Interferometric Synthetic Aperture Radar (A-InSAR) techniques are among the most effective methods for simultaneously monitoring multiple critical infrastructures, utilizing freely available Copernicus Sentinel-1 satellite imagery, resulting to a holistic monitoring without cost[2]. Specifically, techniques such as Persistent Scatterer Interferometry (PSI)[3] and Small BAseline Subset (SBAS)[4] can detect potential displacement rates with an accuracy of millimeters to centimeters level. Several studies proved that the above-mentioned techniques serve as an important tool for estimating and monitoring the displacement rates in cases of critical infrastructures using remote sensing[5–9]. The monitoring of displacements on the coastal zone areas is challenging due to their dynamic environment[10–13]. This study aims to use the above-mentioned techniques, exploiting the characteristics of the Copernicus Programme and its Sentinel-1[14] SAR imagery to identify potential displacements in fishing shelters in Cyprus. After discussions with the national authorities responsible, i.e., the Department of Fisheries and Marine Research (Ministry of Agriculture, Rural Development, and Environment) and the Department of Public Works in Cyprus (Ministry of Transport, Communications

Tenth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2024), edited by A. Christofe, S. Michaelides, D. Hadjimitsis, C. Danezis, K. Themistocleous, N. Kyriakides, G. Schreier, Proc. of SPIE Vol. 13212, 1321212 · © 2024 SPIE · 0277-786X · doi: 10.1117/12.3037294

and Works), one region, the fishing shelter of Agios Georgios in Pegeia region, was selected as pilot site for further investigation.

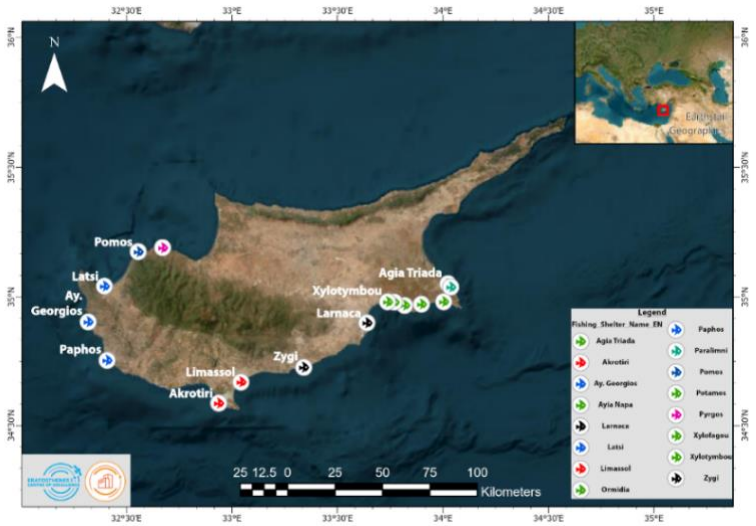

Figure 1: Fishing Shelters across the coastal zone of Cyprus

2. STUDY AREA

The Agios Georgios Pegeias fishing shelter is located in the area of Mandoullis of Agios Georgios Pegeias in Paphos and has a capacity of about 20 vessels, as shown in Figure *2*. The fishing shelter was built in 1981 and since then, various improvements have been made. The fishing shelter took the form it has today in 2007. Exactly opposite the Agios Georgios fishing shelter there is a small island named Geronisos. Geronisos island stirs the interest of explorers and archeologists since it is a shelter for numerous birds, mainly seagulls, and presents archaeological remains. Additionally, Agios Georgios Pegeias fishing shelter offers panoramic views of the Mediterranean Sea. Therefore, the fishing shelter has, among others, a social, economic and tourist impact in the region[15], developing the necessity to be further monitored.

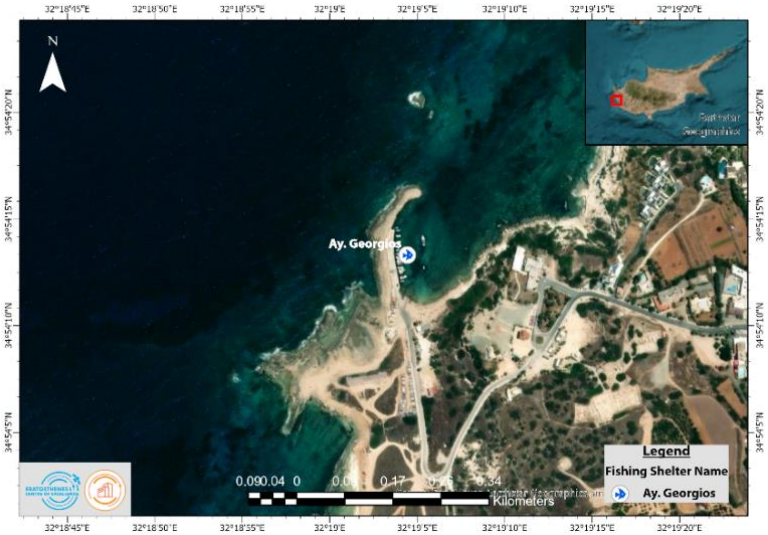

Figure 2: Map of the Agios Georgios fishing shelter in Pegeia, Paphos

3. METHODOLOGY

Data

The study utilized open-access data from the Copernicus Sentinel-1A[16] constellation, ensuring the reusability and the expansion of the current endeavor to a larger scale, on a national level. The system of the Sentinel-1 satellites provides a repeat cycle of 6-12 days over Cyprus, functioning in C-band (5.4 GHz)[17]. The dataset is consisted of 148 Single-Look Complex (SLC) acquisitions in Interferometric Wide (IW) mode with similar characteristics, spanning from January 2019 to December 2023, as presented in Table *1*. Moreover, the acquisitions were obtained in descending mode, from path 167, to ensure comprehensive coverage of the study area. The Vertical-Vertical (VV) polarization mode was selected as the preferable polarization, since it is mostly used for monitoring land displacements[18]. As the primary image of the dataset, the 30th of June 2021 was selected, since it minimizes the spatial and temporal decorrelation between the baselines of the acquisitions[19].

Table 1: Calendar of Sentinel-1A dataset from 2019-2023

Month	**2019**	**2020**	**2021**	**2022**	**2023**
January	12, 24	07, 19, 31	01, 13, 25	08, 20	03, 15, 27
February	05, 17	12, 24	06, 18	01, 13, 25	08, 20
March	01, 13, 25	07, 19, 31	02, 14, 26	09, 21	04, 16, 28
April	06, 30	12, 24	07, 19	02, 26	09, 21
May	12, 24	06, 18, 30	01, 13, 25	08, 20	03, 15, 27
June	05, 17, 29	23	06, 18, **30***	01, 13, 25	08, 20
July	11, 23	05, 17, 29	12, 24	07, 19, 31	02, 14, 26
August	04, 16, 28	10, 22	05, 17, 29	12	07, 19, 31
September	09, 21	03, 15, 27	10, 22	05, 17, 29	12, 24
October	03, 15, 27	09, 21	04, 16, 28	11, 13	06, 18, 30
November	08, 20	02, 14, 26	09, 21	04, 16, 28	11, 23
December	02, 14, 26	08, 20	03, 15, 27	10,22	05, 17, 29

Data Processing

The processing of the dataset followed the PSI methodology. PSI workflow methodology was divided into three (3) main parts, as presented in Figure *3*. The first part regards the pre-processing methodology of the dataset, in order to prepare the dataset for the PSI processing. Specifically in this part, the single-primary Differential Interferometry SAR (DInSAR) processing using the ESA SNAP v10.0 was conducted. The pre-processing was conducted using the open-source toolbox "snap2stamps" v.2[20]. The second part was carried out using the StaMPS/MTI[21] open-source toolbox. Following the first part, the selection of the PS candidates based on the coherence performance along with their statistics, the phase unwrapping and the filtering in each pair were applied using the Matlab[22] software. Finally, the calculation of the LoS displacements of each PS were exported, enabling the visualization of the results. The latter was performed leveraging the ArcGIS Pro software, powered by ESRI.

Additionally to the satellite data, the primary sources that drive the current study include a DEM and external shapefiles. The Shuttle Radar Terrain Model (SRTM)[23] from USGS was used as the external DEM. Regarding the shapefiles of the fishing shelters in Cyprus, those are obtained from the Department of Fisheries and Marine Research which is under the Ministry of Agriculture, Rural Development and Environment.

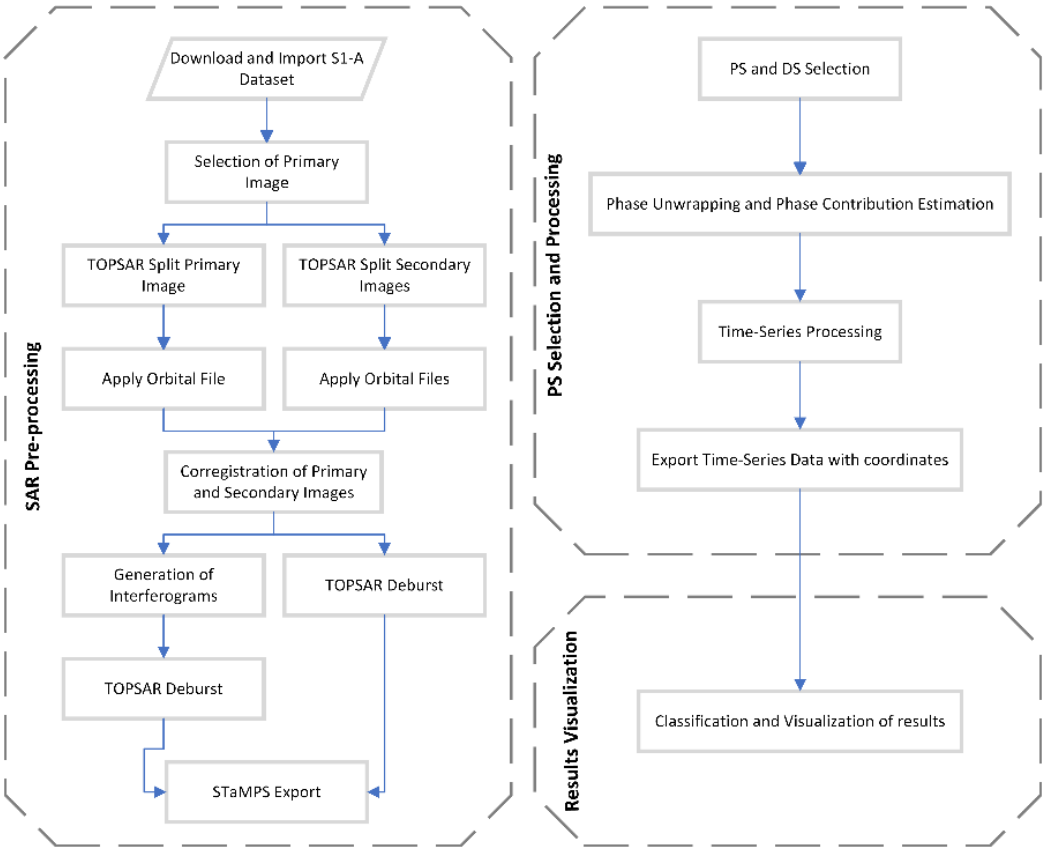

Figure 3: Overall methodology of PSI processing.

4. RESULTS AND DISCUSSION

Following the PSI methodology along with the additional resources, the geographic information of the PSs along with the LoS displacements were presented in Figure *4*. The results were classified into six (6) classes for visualization purposes, covering the LoS displacement range of -6.0 mm/year to 4.5 mm/year. The results of the PSI processing indicated displacement rates up to -5 mm/year, especially at the edge of the fishing shelter. It is noteworthy that the geolocation of the points needs to be improved since no reliable reference point was selected during the data processing. Overall, the fishing shelter of Agios Georgios Pegeias seems to be stable except from the edge of the fishing shelter.

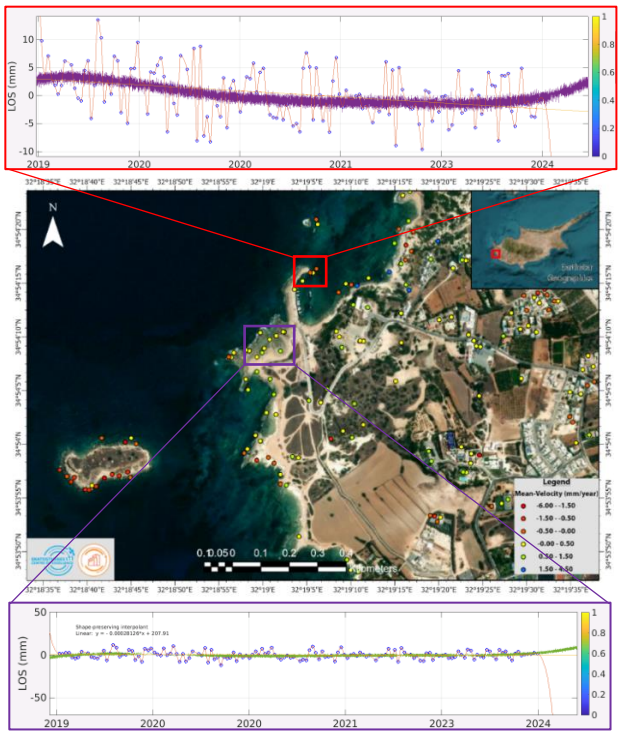

Figure 4: Displacement map of Agios Georgios Pegeias fishing shelter in Paphos, Cyprus

5. CONCLUSION AND FUTURE STEPS

The current study presents the preliminary results of monitoring fishing shelters in Cyprus using advanced InSAR techniques, and specifically the Agios Georgios Pegeias fishing shelter as the pilot study. Detected displacements using the A-InSAR techniques, such as the PSI showed an average LoS displacement rate up to -5 mm/year over the five-year study. This rate could be related to the design / construction condition or the swelling of the infrastructure as the structure is built in the sea. The importance of displacement monitoring fishing shelters in Cyprus is essential for the continuous monitoring of the stability of the infrastructure, ensuring the safety and resilience of the fisheries, the public and the broader environment. Through the knowledge transfer and close collaboration between the above-mentioned organizations, the displacement rates were successfully calculated. The current study is the beginning of continuous monitoring of critical infrastructures in Cyprus, including structures such as fishing shelters and dams in Cyprus, on a national level.

Last but not least, the study will be reinforced in multiple ways. Specifically, the analysis of the ascending dataset will provide a more sufficient understanding of the displacement rates. Following the latter, the decomposition of displacements in ascending and descending modes will result in retrieving the E-W-U components, enabling the comparison with geodetic measurements. Finally, the processing analysis can be carried out using various software and toolboxes such as the ISCE and SARscape and compare the differences or the accuracy that the results showed.

ACKNOWLEDGEMENTS

The authors acknowledge the 'EXCELSIOR': ERATOSTHENES: Excellence Research Centre for Earth Surveillance and Space-Based Monitoring of the Environment H2020 Widespread Teaming project (www.excelsior2020.eu). The 'EXCELSIOR' project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 857510, from the Government of the Republic of Cyprus through the Directorate General for the European Programmes, Coordination and Development and the Cyprus University of Technology.

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