# INSAR MONITORING OF FAIAL AND PICO ISLANDS (AZORES), FIRST RESULTS

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## ABSTRACT

The persistent scatterers technique was tentatively implemented and evaluated on Faial and Pico islands (Azores archipelago). Two non consecutive years of ENVISAT-ASAR C-band images in descending mode were used, from March to October 2004 and from March 2006 to June 2007. The interferograms show poor coherence due to temporal decorrelation, high vegetated areas and high atmospheric variability compromising the interferogram analysis and interpretation. The PS technique was applied to overcome the reduced coherence problem, but the low number of available SAR acquisitions limits the amount of accepted PSC (Persistent Scatterers Candidates), less than 1 PS/Km$^2$. In this paper the main results of INSAR processing and PS technique feasibility over these islands will be illustrated and analyzed.

## 1. INTRODUCTION

The Azores Archipelago is located near the triple junction (ATJ) between Eurasia, Nubia and North American plates. The complex geological setting of the Azores plate boundary is responsible for significant seismic and volcanic activity that has already caused tens of deaths and mayor damage in the last century. Although the present-day plate boundary between Eurasia and Africa appears to cut across the Azores Archipelago, the fine scale geometry and exact location of this active plate boundary area remains unclear.
The main goal of KARMA (Kinematics And Rheological Modelling of the Nubian-Eurasian plate boundary in Azores) is to derive a kinematic model for the Azores plate boundary and to design a comprehensive model for the Eurasia/Nubian plate boundary. This will be achieved by the development of an integrated technique, based on SAR interferometry, GPS surveys, continuous GPS observations and rheological modelling, to evaluate inter-seismic, co-seismic and post-seismic deformation.
This work was developed in the scope of KARMA's WP-2 (InSAR Determination of the Surface Displacement Field) and the main objectives were:

a) to analyze the potential of natural corner reflectors (man-made features) for InSAR time series studies in comparison with artificially ones,
b) development of tools to automatically extract relevant information from SAR images for ground monitoring,
c) test the applicability of corner reflectors in Faial Island with the purpose of reducing the number of GPS points for surface monitor deformation processes;
d) integration and systematic validation of different types of observations (GPS + InSAR), complementary and/or redundant to analyze possible artifacts (site effects, meteorological influences), and estimate a "realistic" uncertainty of measurements.

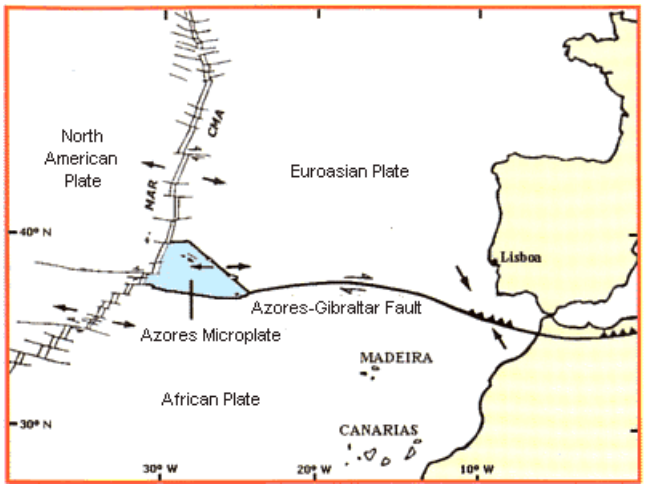


**Figure 1.** Map showing the Mid-Atlantic Ridge splitting Azores and separating the North American and Eurasian Plates. http://www.kilimanjaro.cc/volcanoes/azores.htm

On Faial and Pico the applicability of INSAR was already demonstrated on the 9$^{th}$ July 1998 Mw 6.1 earthquake [1]. In that study, only six ERS1-2 SAR images in descending mode, between June 1992 and November 2000 were used. Some difficulties on the deformation evaluation were reported even though a significant deformation was monitored by GPS.
In this study, the first results of INSAR applied for slow deformation monitoring on Faial and Pico will be presented and analyzed.

## 2. SAR DATA AND INTERFEROMETRIC ANALYSIS

The images used in this study, were acquired by the ENVISAT satellite from the European Space Agency (ESA), in C band with 5.6 cm wavelength. The selection of these images before the beginning of the project brought some limitations; only a few images were available in the ESA archives, due to the fact that the radar was frequently turned off over the Atlantic. The data selection was specified according to the characteristics shown in table 1. At the time of this paper, 23 descending and 17 ascending mode images were acquired, and it was possible to process 19 (descending) and 17 (ascending) images.

Table 1. Images characteristics

| Latitude Longitude | Perpendicular baseline (m) | Temporal Baseline |
|---|---|---|
| 38,53 -28,59 | -1000 a 1000 | 2004 - 2006 |
| **Track** | **Passage** | **Orbit** |
| 052 | Descending | 11128 – 29164 |
| 417 | Ascending | 21012 - 29028 |

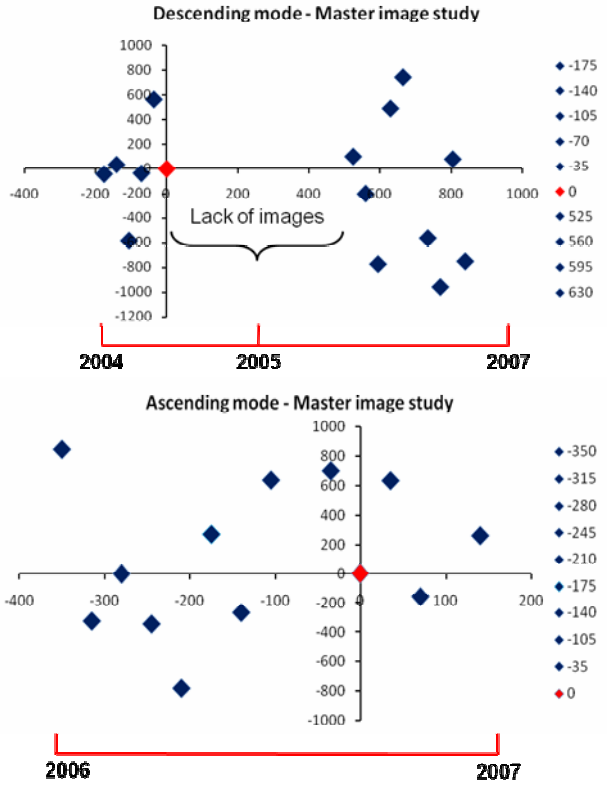


Figure 2. Master study: descending mode and ascending mode.

## 3. PROCESSING

DORIS software was used for interferometric processing, as developed by Delft University of Technology, (http://enterprise.lr.tudelft.nl/doris/).

The major difficulty in the interferometric processing is the image coregistration due to the minimal amount of land area and coherence limitations due to the lush vegetation. In figure 3 an output plot of the offset vectors is shown, for the coregistration of a pair with -585.6 m and -105 days of perpendicular and temporal baselines, respectively.

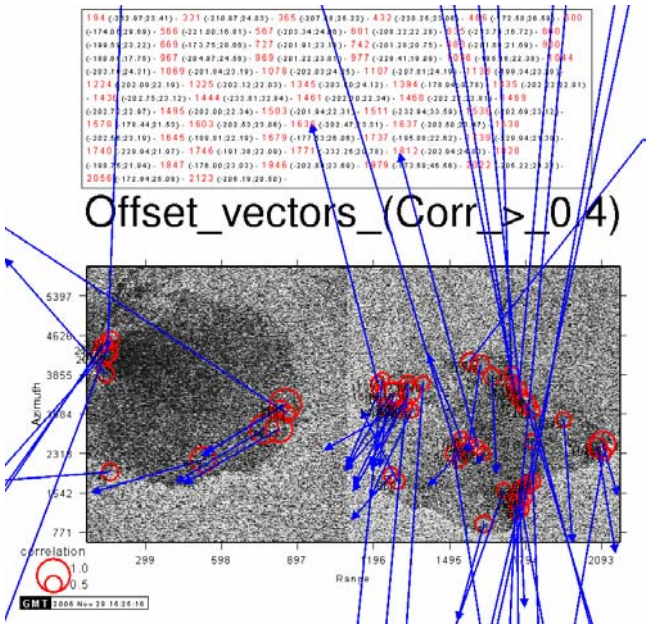


Figure 3. Offset vectors for coregistration. These vectors show that large outliers had to be removed to retrieve correct alignment.

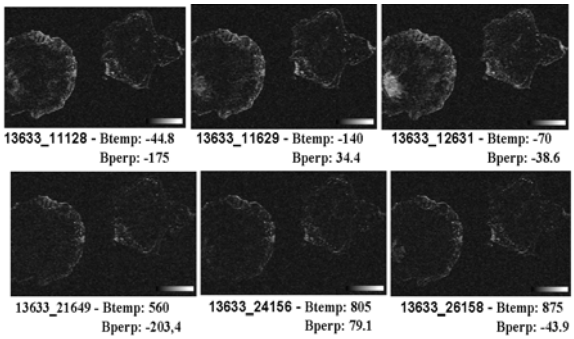


Figure 4. Coherence according to temporal and perpendicular baselines

It was verified that the coherence is strongly dependent on the perpendicular baseline, resulting in reduced coherence with increasing baseline, while it was less dependent on the temporal baseline. This fact is

illustrated in figure 4 where the coherence is shown as a function of temporal and perpendicular baselines.

## 4. PERSISTENT SCATTERERS

A first run of the Persistent Scatterers technique was attempted in order to detect the displacements and also to reduce the coherence limitations, using the stack of the interferograms already processed. As anticipated, the amount of available images is at this time still too low for successful atmospheric phase screen estimation and, consequently, the unambiguous identification of coherent scatterers. It was applied over 16 interferograms, and after a large number of tries only 53 PS were identify over Faial Island, which turns into less than 1 PS/Km$^2$, see figure 5.

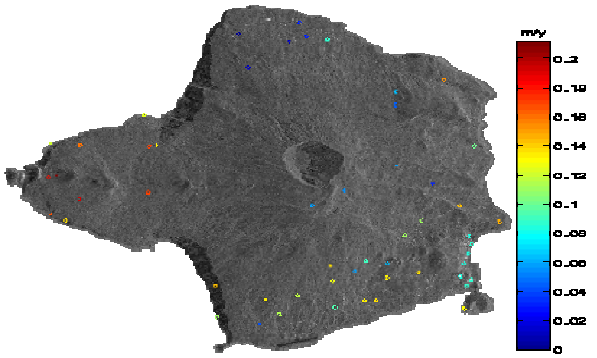


Figure 5. Magnitude image with the first distribution of Persistent Scatterers detected over Faial Island, using only 16 interferograms.

These first intermediate results are likely to be due to (i) the fact that not enough images were available for coherent target identification, related to the first order estimation of atmospheric phase screen, topography, deformation, and phase ambiguities, (ii) the limited number of man made structures on the island and (iii) the strong degree of temporal decorrelation as a result of dense vegetated and lush areas covering almost all the island. Only the Capelinhos area, in the West, shows a different land cover, brown sand and ashes from the 1957 eruption, and the urban area on East, see figure 6.

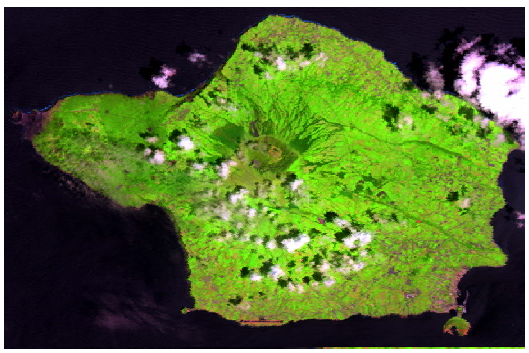

Figure 6. Landsat image of Faial.

## 5. CONCLUSIONS

Although the PS technique has been successfully used elsewhere, on Faial the results currently suboptimal, mainly due to the limited amount of available SAR images. All parameters were tentatively fine-tuned and even though only 53 PS were determined, their velocity estimates are in agreement with recent GPS surveys. In order to improve the performance of the PSI analysis, we anticipate that when 25 or more images are available, results will become more successful. Moreover, to increase the number of PS we plan to install some corner reflectors on strategic points increasing the network connectivity and probably the number of PS.
The atmospheric effects will be studied and meteorological data will be use to model atmospheric artefacts.

## ACKNOWLEDGEMENTS

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