PTDC/CTA-GEO/2083/2021
Progress Report – Scientific Component

Progress Report nº 1

1. Period:
Starting Date: 01-01-2022
End Date: 31-12-2022

2. Summary of the Activities carried out and deviations to the approved proposal

Figure 1 shows the planned activities by Working Package (WP) for the first year of the GEMMA project.

Tasks	Year 1											
	2022											
	1	2	3	4	5	6	7	8	9	10	11	12
T0 - Management and Dissemination	A1.0		D0.1									D0.2
T1 - GNSS & Gravity Observations & Products									A1.1		D1.1	D1.2
T2 - Flexure Modeling												
T3 - Seismic Anisotropy Tomography and Shear-wave Splitting Analysis												
T4 - Island Tilting Assessed by Magnetic Methods							A4.1					
T5 - Multiscale Seafloor Structural Analysis												D5.1
T6 - Geodynamic Modelling												
T7 - Conciliatory Model												
Milestones									M1			M2
Milestone												
M1 - End of main field campaigns												
M2 - Progress Report (1st Year)												
Activites/Deliverables (Expected Outputs)												
A1.0 Kick-off Meeting												
D0.1 Web site (http://segal.ubi.pt/GEMMA)												
D0.2 Yearly Report												
A1.1 First GNSS & gravimetric campaign in Azores												
D1.1 First GNSS horizontal and vertical velocity fields for Macaronesia												
D1.2 First Strain rate maps at Macaronesia and Archipelagos' Scale												
A4.1 Field Campaign in Santa Maria and São Jorge.												
D5.1 Compilation of multibeam and seismic reflection database												

Figure 1 – GEMMA Timeline for first year

2.1 Summary of the Activities

WP0 Management and Dissemination

The goals of this WP during the first year were reached despite some difficulties, which are natural when a new project starts. The focus was on the optimization of the work, particularly on the interaction between the different WP.

The kick-off meeting was held online on 4th February 2022 with the presence of more than 30 researchers. Presentations were carried out by the different WP Leaders concerning the proposed works to be done. Unfortunately, the document with the minutes of this meeting were not properly saved.

Concerning dissemination, one of the initial tasks was to create the website of the project, which link is https://segal.ubi.pt/gemma. This website describes the project, researchers involved, and the planned activities.

There was a particular focus on hiring the Post-Doc Researcher to be contracted for 36 months in the framework of the project. This was not only necessary from a formal and legal point-of-view (the delaying in contract the researcher could lead to the cancellation of the project) but also because the research plan of the GEMMA project considers very relevant the work to be performed by this researcher (it was planned his/her participation in most of the WP). The process was concluded in July of 2022 with the hiring of Jaime Almeida after a selection among four candidates that were fulfilling all scientific and legal criteria.

Jaime Almeida was introduced to the research team in a meeting that was held on 28th June 2022 (when the selection process was concluded). In this meeting was discussed how Jaime Almeida could be integrated in the project, namely which should be his research priorities.

In this meeting was also discussed the integration of more researchers, namely João Fontiela, Nuno Dias, David Schlaphorst, and Gonçalo Henriques, which was approved by all participants. The integration of these members (and the reintegration of Marta Neres) was requested to FCT, which has approved it. The minutes of this meeting are available at https://segal.ubi.pt/gemma/docs/meeting-2022june28.pdf.

Concerning changes in the research team, one negative aspect was the request from Machiel Bos to reduce his participation in the project due to unexpected changes in his professional life (he has decided to not continue in precarious position as post-doc researcher in academia and moved to the private sector). His contribution was important in several tasks, namely the coordination of the activities of T1.3 (Gravity Field), and WP2 (Flexure Modeling), but he promised to continue assisting the research team, particularly the new post-doc, in acquiring the necessary knowledge to achieve the proposed goals.

It is also very important to stress the coordinated effort of many of the GEMMA researchers (and other colleagues from mainland and Azores) following the seismic crisis in the island of São Jorge that started on 19th March 2022. Several online meetings were quickly organized that allowed the rapid deployment of several types of equipment (seismometers, GNSS receivers) to monitor the crisis. The acquired observations were very important to assist the authorities evaluating the situation during the crisis. In addition, it was acquired an invaluable set of data that will be used by the GEMMA researchers in understanding the geodynamics of the region, one of the most important goals of the project.

WP1 GNSS & Gravity Observations & Products

The planned activities on this task for the first year was to carry out a dedicated GNSS and gravimetric campaign in the Azores, namely in the Central group of the archipelago. However, two major events led to a significant change of the initial plans: (a) the seismic crisis in São Jorge; (b) the unavailability of Machiel Bos to participate in the planned gravimetric campaign.

The most probable cause for the 2022 seismic crisis in São Jorge was a magmatic intrusion that started at 10-15 km depth and could have reach 7-8km or less. The superficial manifestation of the intrusion has been observed since the beginning of the swarm using Synthetic Aperture Radar (SAR) data acquired by Copernicus Sentinel-1 with line-of-sight deformations of the order of 10 cm estimated at the affected area after the first two weeks.

The GEMMA team assisted directly in the acquisition of GNSS data during the seismic crisis in São Jorge by installing four GNSS stations in a semi-permanent mode (they continued to observe until the end of the year).

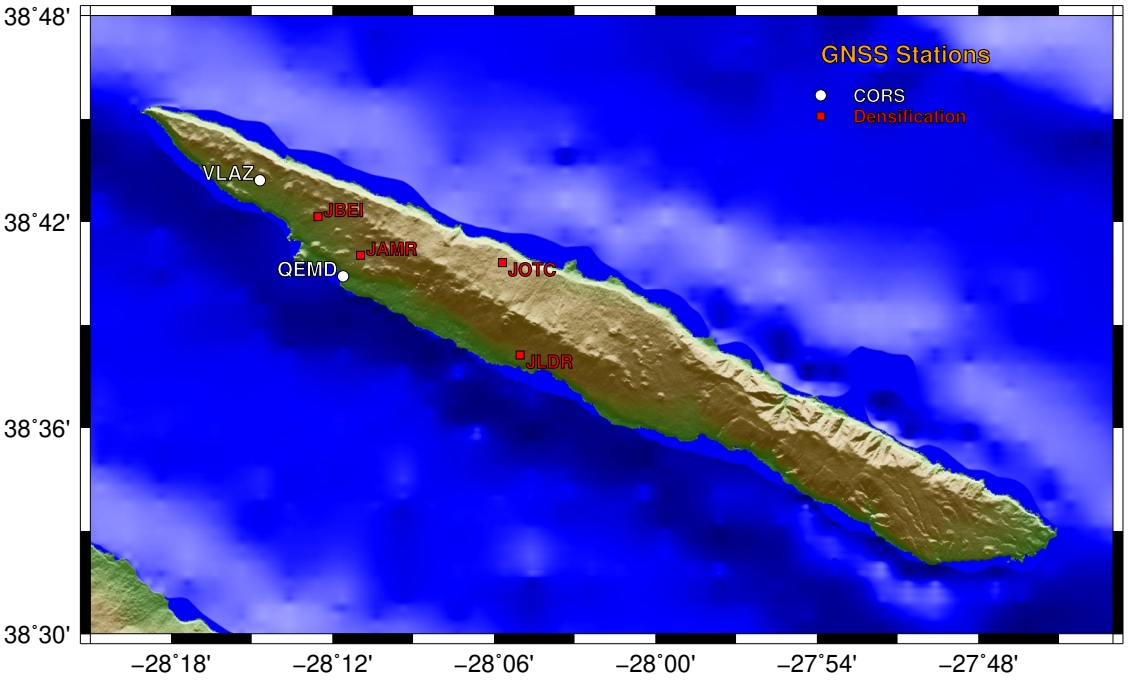

Figure 2 – Distribution of the GNSS stations in São Jorge managed by the GEMMA team

Initial results of the the horizontal and vertical velocity fields derived from this dense network, augmented with existing stations in the other islands (cf. Figure 3), has allowed us to create near- and far- models for the deformations caused by this event.

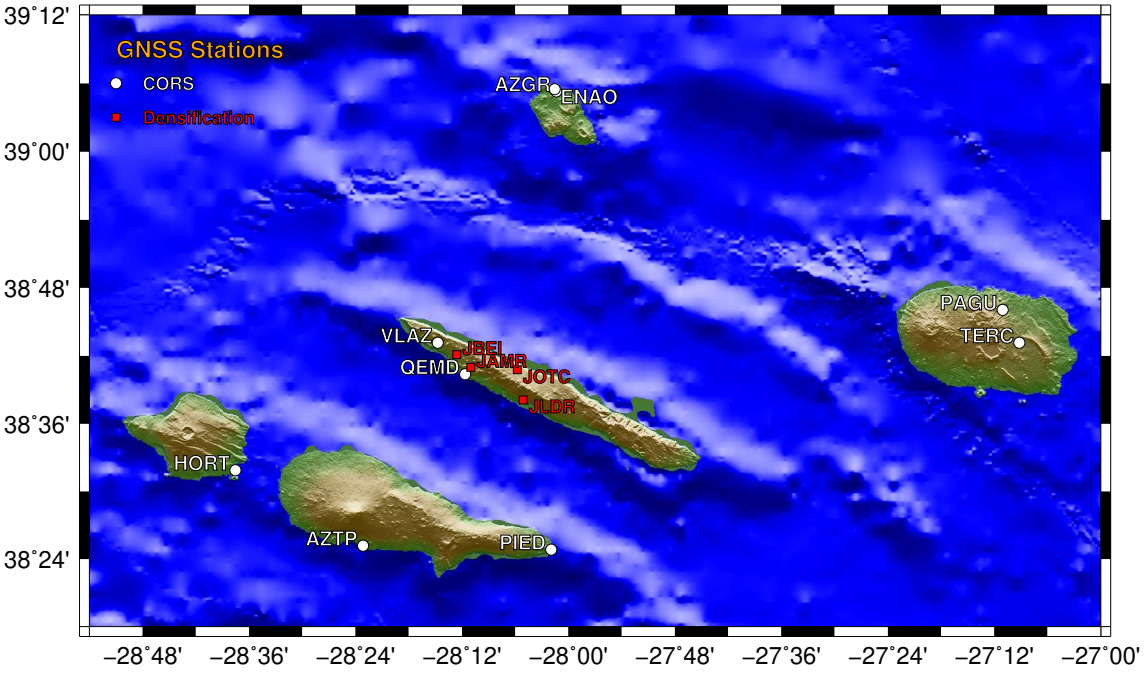

Figure 3 – Distribution of the GNSS network in the Central Group available to the GEMMA team

Displacements between the islands were estimated both at the near-field and far-field as it is shown by Figure 4 and Figure 5, respectively, for the horizontal component.

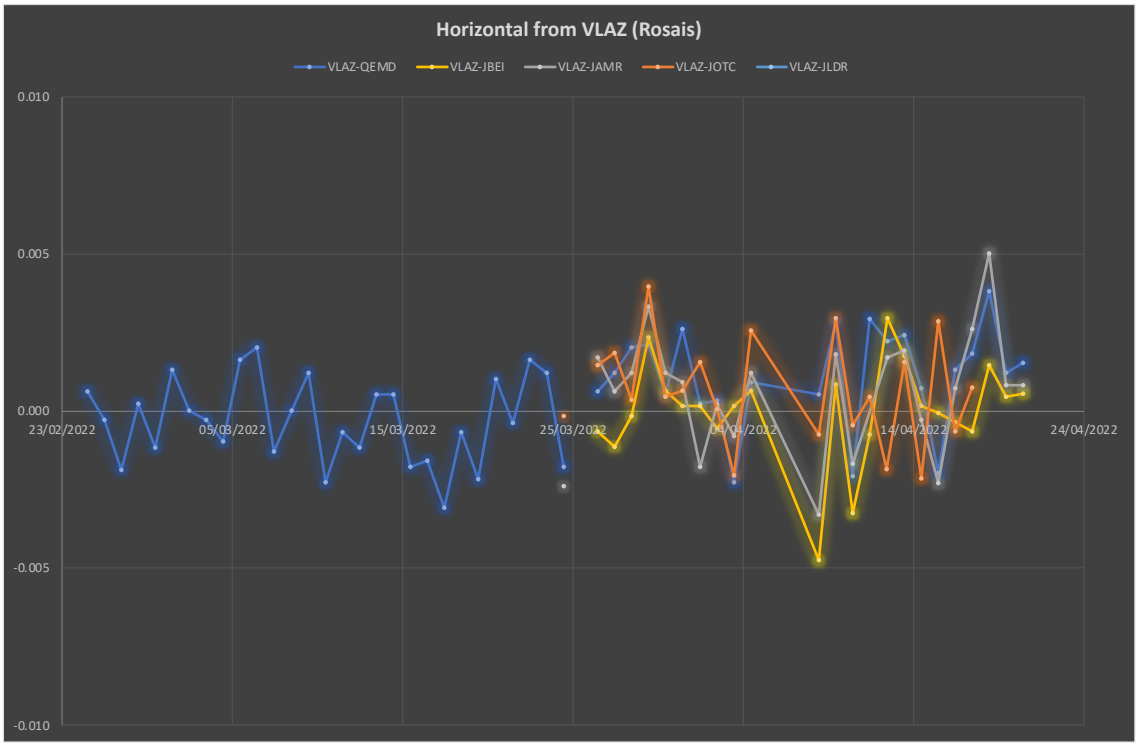

Figure 4 – Near-field displacements observed in São Jorge island (VLAZ station)

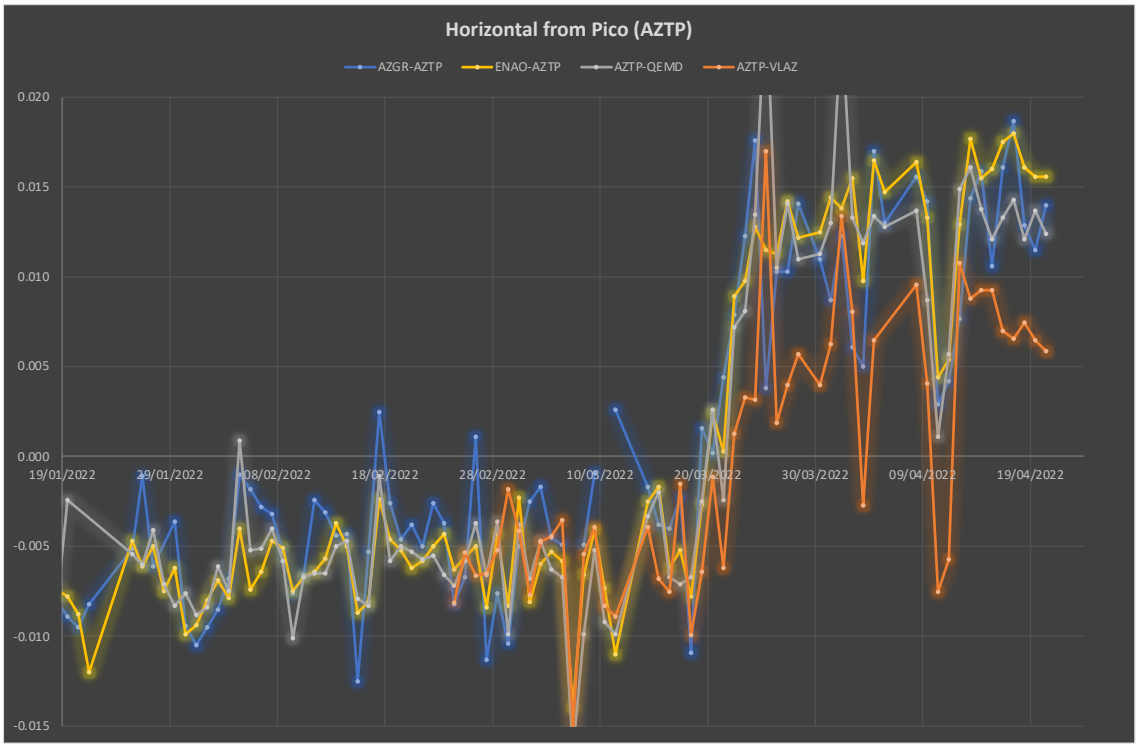

Figure 5 – Far-field displacements observed from Pico island (AZTP station)

The results have shown that most of the near-field deformation has occurred in the first days reaching about 6cm internally in São Jorge. The dense GNSS network was not able to detect any significant intra-island deformation after 5 days of the begin of the seismic crisis. This indicates that most of the deformation was carried out in the first days of the event.

The far-field deformation, particularly in the direction of Pico (AZTP) – São Jorge (QEMD) – Graciosa (AZGR, ENAO) reached opening rates equally to 1-2 times the expected motions per year due to the plate tectonics.

WP2 Flexure Modeling

The goal of this WP during the first year of the project was to construct a viscoelastic flexure map for the Macaronesia archipelagos. Jaime Almeida began working on this WP in July, after being contracted. Due to a lack of basis on this subject, he has since been undergoing training on the development and maintenance of the gravity modelling software (i.e., CARGA), under supervision of the task leader Machiel Bos. This training has so far focused on the Madeira archipelago, including data collection, curating, and processing; with the current output of the task being a model for the gravity anomaly of this region (Figure 2).

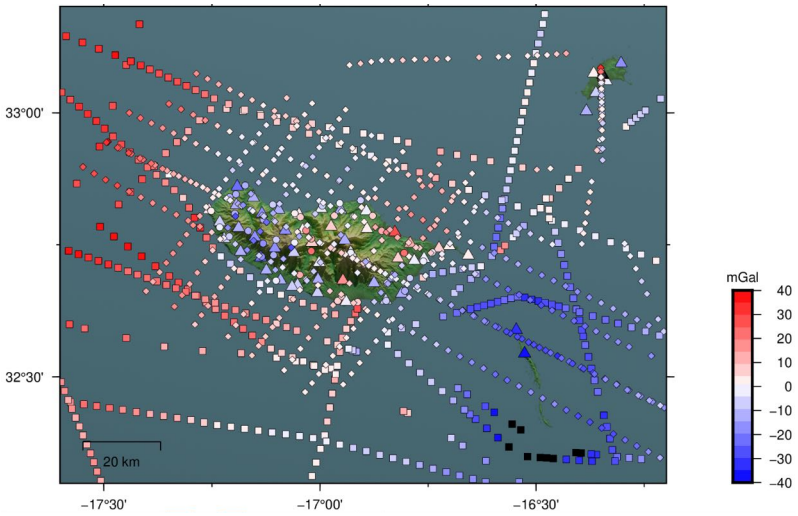

Figure 6 – Vening-Menesz gravity anomaly model for the Madeira archipelago.

WP3 Seismic Anisotropy Tomography and Shear-wave Splitting Analysis

The aim of this work page (WP) is to obtain a 3D model of the isotropic and anisotropic shear-wave lithospheric structure in the GEMMA study region. In 2022, we have we reviewed the results from a number of studies on the seismic mantle structure beneath Azores, Madeira, Canaries and Cape Verde archipelagos, which include seismic tomography, receiver functions, PP and SS precursors and shear-wave splitting measurements. This review has been accepted for publication in Frontiers in Earth Science. Still in 2022, a PhD student, under the supervision of Ana Ferreira started an anisotropic surface wave tomography to obtain a 3D isotropic and radially anisotropic shear-wave structure in the mantle and in the crust. Shear Wave Splitting (SWS) analysis across the Azores islands will the done in the 2023 and integrated with the already obtained and published SWS results for Madeira and Canaries. Although not, initially foreseen, In the aftermath of the São Jorge seismic crisis, we decided to perform a study of the temporal seismic velocity changes associated with the swarm of events.

WP4 Island Tilting Assessed by Magnetic Methods

No activities have been carried out in this first year related with this Working Package due to personal issues related with the members responsible for this Working Package. It is expected to be done during the next year.

WP5 Multiscale Seafloor Structural Analysis

The aim of this WP during the first year was to compile all the available high-resolution bathymetry and seismic reflection data. We identified all the organizations that have these types of data and started to contact them. Unfortunately, some of them (e.g., IFREMER) were not available to share the data. Others have not yet replied to our contact. Due to that we have only a limited source of data owned by the partners of this project and the public data available such as the EMODNET bathymetry. We will continue our efforts to do the best compilation possible to start as soon as possible the next subtask which involves the analysis of the tectonic structures on the seafloor to check if they are compatible with the patterns of vertical and horizontal movements given by the GNSS & gravity observations (T1) and the flexural modelling (T2).

WP6 Geodynamic Modelling

The goal of this work package (WP) is to develop advanced numerical geodynamic models that incorporate new observational data and test different conceptual hypotheses that arise from the previous work packages and tasks. Although this WP is set to start in the beginning of the second year of the project, preliminary models have started to be developed, for two reasons. The first is that the hired post-doc (Jaime Almeida) is particularly skilled in geodynamic modelling. Second, this kind of model takes significant time to develop, debug and to ensure coherence/stability. Thus, this will allow us to gain some time ahead in the project. Two base models have been developed so far using the code LaMEM: 1) regional models at the scale of the Terceira Rift and individual islands; 2) Large scale-models simulating reconstructions and scenarios regarding the establishment of the entire triple-junction, the Azores plateau, the West Gloria Fault and mid-Atlantic ridge (cf. Figure 7). Plumes, weak zone and different geometric and kinematic configurations will be tested next.

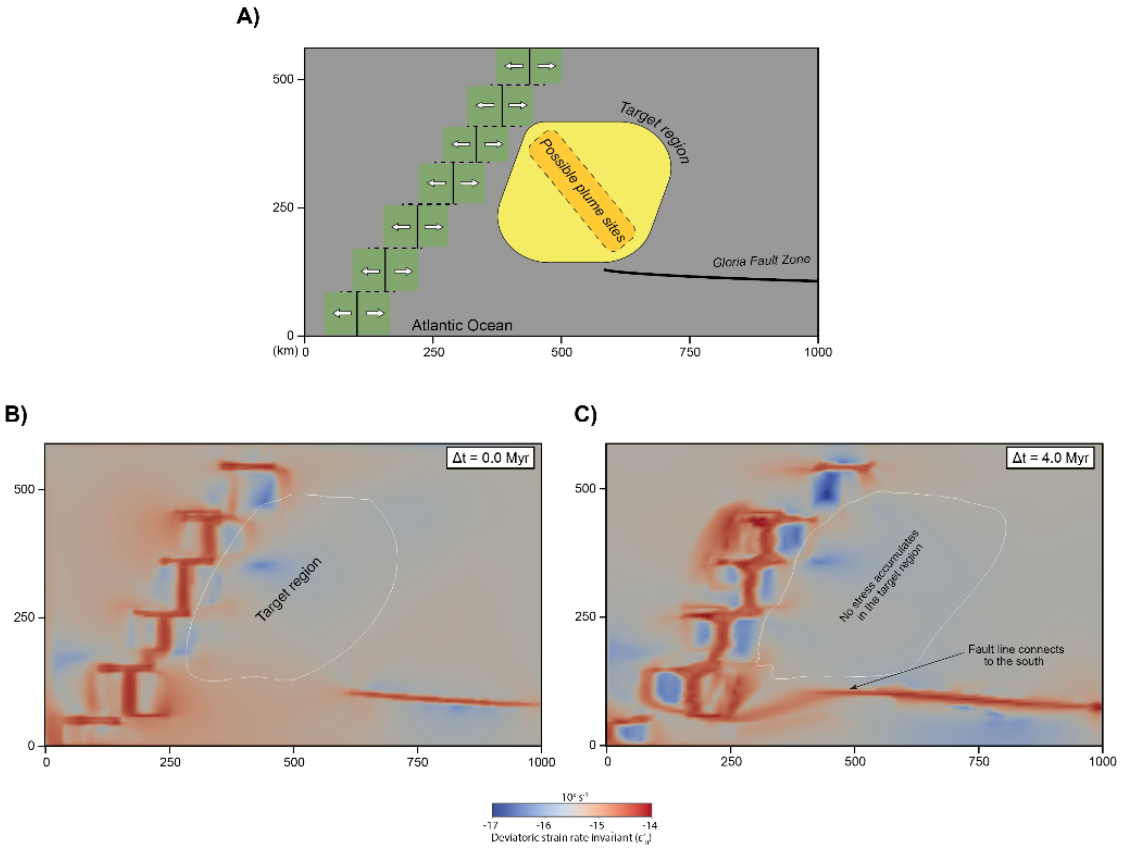

Figure 7 – Base models for the Azores region

WP7 Conciliatory Model

Although this task is set to start in the second semester of the second year, a minimum of integration of the results from the WPs 2 to 5 was necessary to start developing the geodynamic numerical models (WP6). This involved enunciating a number of simple tentative hypotheses that will be essential to set the initial/boundary conditions for the numerical models, and to identify the key parameters to be tested. This will allow the conciliatory model to be progressively developed and intermediate stages to be tested using numerical models.

2.2 Desvios à Proposta Aprovada

The deviations to the proposal were already described in the decription of the activities carried out by the different work packages.

3 Publicações

Conferences Abstract/Papers (International)

Fernandes, R. M. S., Ramalho, R., Miranda, J. M. A., González, P. J., Prates, G., Henriques, G., ... & Fernandes, J. M. (2022, December). Investigating the 2022 Seismic Crisis of S. Jorge, Azores, using GNSS and Satellite Radar Interferometry. In AGU Fall Meeting Abstracts (Vol. 2022, pp. NH13A-02).

4. Indicadores de Realização Física

Neste quadro deve indicar os valores referentes ao período a que corresponde o Relatório de Progresso.

Neste quadro deve apenas indicar concretizações efectivas. Não indique publicações submetidas para publicação, nem teses que ainda não tenham sido discutidas.

Indicadores	Quantidade realizada
A - Publicações	
Livros	0
Artigos em revistas internacionais	0
Artigos em revistas nacionais	0
B - Comunicações	
Comunicações em encontros científicos internacionais	1
Comunicações em encontros científicos nacionais	0
C - Relatórios	1
D - Organização de seminários e conferências	0
E - Formação avançada	
Teses de Doutoramento	0
Teses de Mestrado	0
Outras	0
F - Modelos	0
G - Aplicações computacionais	0
H - Instalações piloto	0
I - Protótipos laboratoriais	0
J - Patentes	0
L - Outros	0