

PORTUGAL

**SECÇÃO PORTUGUESA DAS UNIÕES INTERNACIONAIS
ASTRONÓMICA E GEODÉSICA E GEOFÍSICA
(SPUIAGG)**

**INTERNATIONAL ASSOCIATION OF GEODESY
IAG**

NATIONAL REPORT

2011 – 2015

**PRESENTED TO THE XXVI GENERAL ASSEMBLY
OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS**

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Coordinated by

**Eng. João Manuel Agria Torres,
National Correspondent of IAG**

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1 – FORWARD

The present report contains the information about the work carried out in Portugal in the field of Geodesy, covering the period 2011-2015.

Each one of the following chapters is dedicated to the institutions (governmental agencies, universities and research centres), who reported relevant geodetic work:

- *Direção-Geral do Território (Directorate-General for Territorial Development)* - report by Eng. José Sebastião Chaves;
- *Laboratório Nacional de Engenharia Civil (National Laboratory of Civil Engineering)* – report by Prof. João Casaca and Dr. José Nuno Lima;
- *Faculdade de Ciências da Universidade de Lisboa (Faculty of Sciences of the University of Lisboa)* – report by Prof. João Catalão;
- *Observatório Astronómico Prof. Manuel de Barros da Universidade do Porto (Astronomical Observatory Prof. Manuel de Barros of the University of Porto)* – report by Prof. Luisa Bastos.

2 – DIREÇÃO-GERAL DO TERRITÓRIO (*DIRECTORATE-GENERAL FOR TERRITORIAL DEVELOPMENT*)

2.1 – Introduction

Since the 24th January 2012 (Decreto-Lei n.º 7/2012) the Direção-Geral do Território (DGT) - *Directorate-General for Territorial Development* succeeded the former Instituto Geográfico Português (IGP) – *Portuguese Geographic Institute*, and the Direção-Geral do Ordenamento do Território e Desenvolvimento Urbano (DGOTDU) - *Directorate-General for Spatial Planning and Urban Development* and also the Gabinete Coordenador do Programa FINISTERRA (GCPF) – *Coordinate Cabinet for the FINISTERRA Program*.

Directorate-General for Territorial Development (DGT) is the National Authority for Geodesy, Cartography and Cadastre, as well as Territorial and Spatial Planning. Therefore one of its main missions is the establishment and maintenance of the Portuguese Reference Systems and National Frames.

In the Geodesy domain, DGT's most important projects are:

- The GNSS Continuously Operating Reference Stations (CORS) network;
- Two acoustic tide gauges (Cascais and Lagos);
- The Relative Gravity Stations Network;
- The High Precision Levelling Network;
- The Geodetic Network.

2.2 – ReNEP – The GNSS CORS Network

In 1997 the DGT installed the first GPS station in Cascais (CASC), near the reference tide gauge, which is in operation since 1882. In the following years, until 2002, seven more stations were installed. From 2012 until 2014 forty new stations were installed, having as main goal the maintenance of the Portuguese Reference Frames.

Since 2006 DGT is being working on the densification and the upgrade of the GNSS CORS network - ReNEP - with two main goals:

- The maintenance of the National Reference Frames;
- To provide a real time precise point positioning service.

At the present time the network consists of 48 CORS: All the stations collect both GPS and GLONASS data and 10 are connected to the high precision levelling network, 42 on the mainland and 6 on the islands (Azores and Madeira Archipelagos).

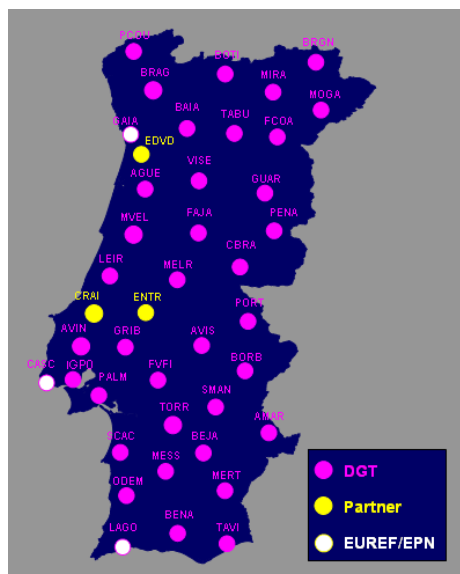


Figure 2.1 – ReNEP Status in Portugal Mainland.

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ReNEP provides data for pos-processing (hourly RINEX files at 5 seconds observation rate) and real time applications.

The real-time corrections are distributed in RTCM format over the NTRIP protocol. There are three different types of products available:

- Network coverage;
- Nearest-site; and
- Single-base station, for those users whose equipments cannot send NMEA messages. Presently there are more than 1700 registered users for real-time applications and more than 700 daily connections to the server.

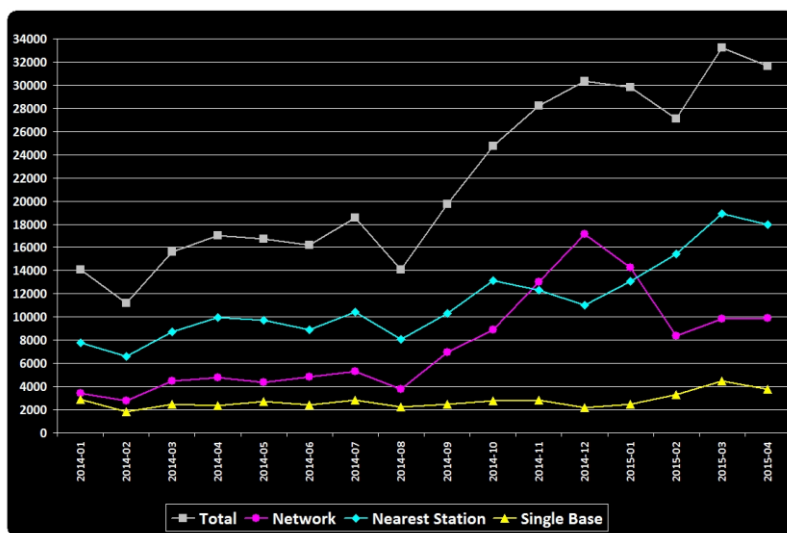


Figure 2.2 – Monthly accesses to ReNEP real-time products.
AC: auto-cell network coverage; NS: nearest site; SBS: single base station.

The tests done in order to evaluate the quality of the real-time positioning service show an average accuracy better than 5 cm in ETRS89, and better than 10 cm when working in the older classical reference systems.

Six of DGT's stations are part of the EPN (EUREF Permanent Network) and 3 of these also belong to the IGS (International GNSS Service Network), providing both RINEX data and the real-time streamings.



Figure 2.3 – ReNEP Stations belonging to EPN and IGS networks.

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DGT participated in EUREF's project "Monitoring of official national ETRF coordinates on EPN web" with its three CORS located in the mainland. The next table shows the differences between the coordinates determined by EUREF and the official DGT coordinates, in ETRF2000 epoch 2000.0.

Table 2.1 – Differences between EUREF publish coordinates and DGT official coordinates for the 3 EPN stations in Portugal Mainland.

Station	Differences		
	X (m)	Y (m)	Z (m)
CASC	-0.020	0.012	-0.005
GAIA	0.022	-0.002	0.016
LAGO	0.001	0.020	-0.007

2.3 – Maintenance of ETRS89

In 1989 Portugal participated in the first GPS campaign promoted by EUREF with the purpose of connecting the European countries. Given that these measurements did not cover appropriately the Iberian Peninsula, a densification network was measured later on in the IBERIA 95 campaign. Between 1999 and 2004 the 1st and 2nd orders geodetic networks (around 1000 trig points) were measured with GPS and connected to the results of IBERIA95. The geodetic network of Portugal mainland is now a realization of the ETRS89, called PT-TM06/ETRS89.

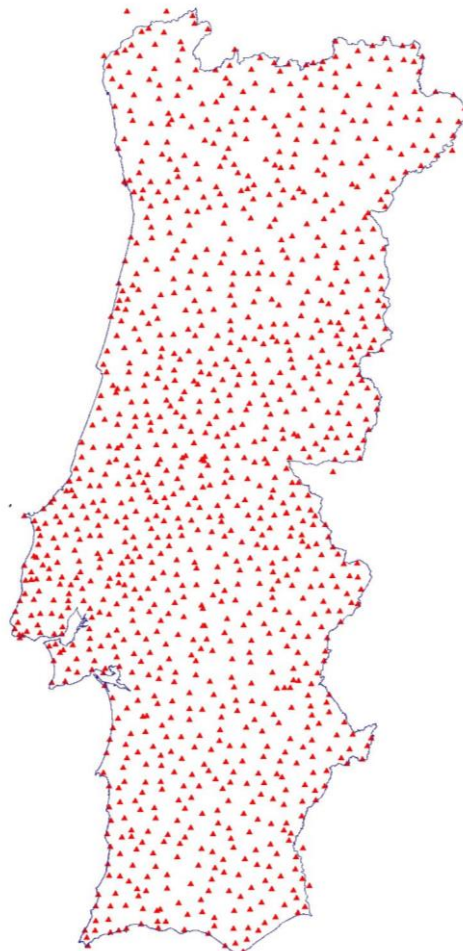


Figure 2.4 – Realization of ETRS89 in Portugal Mainland.

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The Geodetic Network was connected to ReNEP with GNSS measurements. Since nowadays most of the operators make use ReNEP in real-time, it was important to evaluate the consistency between these two networks. To do that, DGT is performing RTK measurements in some points of the Geodetic Network. The differences between the official coordinates and the RTK coordinates are shown in the next table.

Table 2.2 –Differences between official PT-TM06/ETRS89 coordinates and coordinates obtained with RTK measurements.

Differences (m)	X	Y
Max	0.033	0.035
Average	0.000	0.009
Min	-0.018	-0.013
e.m.q.	0.012	0.014

In the Azores and Madeira archipelagos a group of points was measured in the international GPS campaign TANGO1994 (Trans-Atlantic Network for Geodynamics and Oceanography). In the subsequent years the geodetic networks of all the islands were measured with GPS and a realization of ITRS93 (PTRAO8-UTM/ITRF93) was established as the reference frame for the archipelagos.

The parameters for coordinate transformation from the old geodetic reference systems to PT-TM06/ETRS89 and PTRAO8-UTM/ITRF93 were determined. IGP also provide software for coordinate transformation and applications for the transformation of vector data to these new systems.

2.4 – Tide Gauges

DGT is responsible for two acoustic tide gauges, at Cascais and Lagos. The Cascais tide gauge is the reference for the mainland ordnance *datum*. At Cascais there is also a floating tide gauge, installed in 1882 that is still working.

The systems record sea level measurements at 5 seconds rate and all the data are streamed to DGT central office. Both tide gauges contribute with their data to SLEAC (Sea Levels along the European Atlantic Coastline) and IOC (Intergovernmental Oceanographic Commission of UNESCO).



*Figure 2.5 – Cascais Tide Gauges.
Left: Borel Floating System. Right: Acoustic.*

2.5 – Geoid Model

In 2009 the geoid model for Portugal mainland – GeodPT08 - was made available for public download in ASCII format. This model, calculated in cooperation between DGT and FCUL (Faculty of Sciences of the University of Lisbon), is based in the gravity network measurements, and afterwards was adjusted to the levelling and geodetic networks.

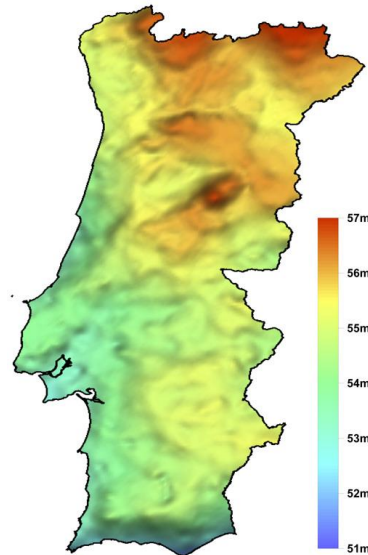


Figure 2.6 – GeodPT08.

In order to evaluate the accuracy of the GeodPT08 RTK measurements were made in leveling benchmarks and geodetic trig points, which were not included in the geoid determination. The average difference between the official orthometric heights and those obtained from RTK and the geoid is 5cm for the leveling benchmarks and 8 cm for the geodetic trig points.

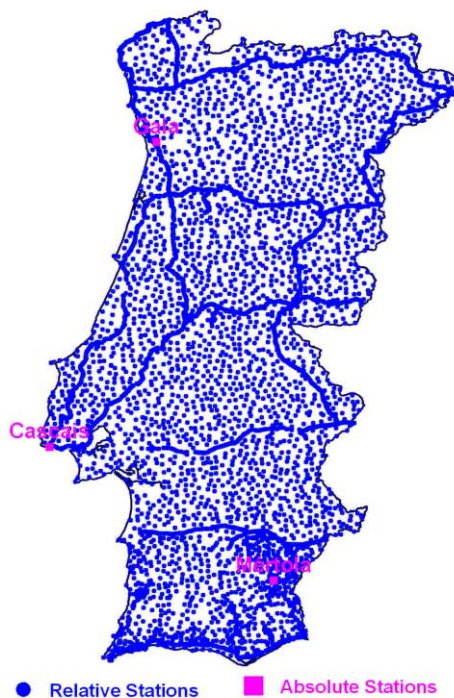


Figure 2.7 – Gravimetric Network of Portugal mainland.

2.6 – EUREF Web Site

Since its creation the EUREF web page is developed by former IGP and currently maintained by DGT. In 2011 the structure and the layout of the web page was rearranged.

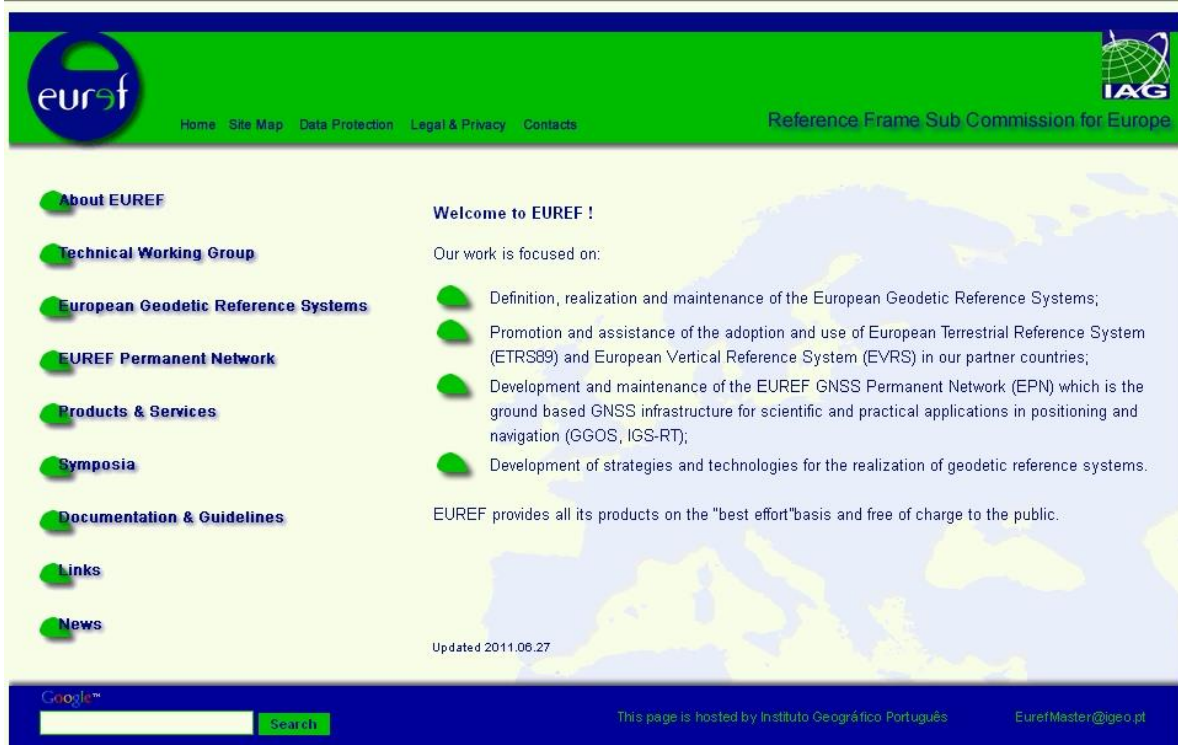


Figure 2.8 – EUREF web site front page

2.7 – Human and Material Resources

The human resources of the DGT Department of Geodesy are five surveying engineers and six surveying technicians.

The equipment consists on:

- GNSS receivers;
- Geodetic levels;
- Optical-mechanics theodolites (astronomy, geodesy and surveying);
- 2 LaCoste & Romberg, model G gravimeters;
- Bernese software;
- Several software for processing the different kinds of geodetic measurements and data.

2.8 – Publications

- M. Vasconcelos, A. Bernardes, P. Patrício (2011) *Avaliação da Implementação do ETRS89 em Portugal Continental*. Resumos da VII Conferência Nacional de Cartografia e Geodesia, Porto, Portugal, pp. 105.
- A. Medeiro, A. Bernardes, M. Figueiredo, M. Vasconcelos (2011) *Comparação dos Registos dos Marégrafos Analógico e Acústico de Cascais entre 2004 e 2010*. Resumos da VII Conferência Nacional de Cartografia e Geodesia, Porto, Portugal, pp. 106.
- C. Martins, M. Vasconcelos (2011) *A Evolução da ReNEP: Produtos, Serviços e Utilizadores*. Resumos da VII Conferência Nacional de Cartografia e Geodesia, Porto, Portugal, pp. 107.
- M. Vasconcelos, A.C. Bernardes, P. Patrício (2012) *Estado da Adoção do ETRS89 em Portugal Continental*. Resumos da 7.^a Assembleia Luso-Espanhola de Geodesia e Geofísica, Donostia – San Sebastian, Espanha.

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- A. Medeiro, A.C. Bernardes, M. Vasconcelos (2012) *Comparação dos Registos dos Marégrafos Analógicos e Acústicos de Cascais*. Resumos da 7.^a Assembleia Luso-Espanhola de Geodesia e Geofísica, Donostia – San Sebastian, Espanha.
- M. Vasconcelos, C. Martins, A.C. Bernardes (2012) *ReNEP- Rede Nacional de Estações Permanentes GNSS: Estado Atual, Produtos, Serviços e Utilizadores*. Resumos da 7.^a Assembleia Luso-Espanhola de Geodesia e Geofísica, Donostia – San Sebastian, Espanha.

2.9 – Presentations

- M. Vasconcelos (2011) *ReNEP – A Rede Nacional de Estações Permanentes GNSS*. Presented at II Colóquio Detecção Remota: Observação da Terra, Sociedade de Geografia de Lisboa, December 2011.
- M. Vasconcelos (2014) *O marégrafo de Cascais e a sua contribuição para a medição do nível médio do mar*. Presented at Sociedade de Geografia de Lisboa, 13 May 2014. (invited)
- H. Silva, A. Medeiro, M. Vasconcelos (2014) *WebTranscoord*. Poster presented at Conferência Nacional de Geodesia, Barreira, Portugal, 15-16 May 2014.
- M. Vasconcelos, A.C. Bernardes, C. Martins (2014) *ReNEP – A Infraestrutura Nacional de Posicionamento por Satélite*. Presented at V Jornadas Ibéricas de Infraestruturas de Dados Espaciais, Lisboa, Portugal, 5-7 November 2014.
- H. Silva, A. Medeiro, M. Vasconcelos (2014) *WebTranscoord – Programa de transformação de coordenadas baseado em software livre*. Presented at V Jornadas Ibéricas de Infraestruturas de Dados Espaciais, Lisboa, Portugal, 5-7 November 2014.
- M. Vasconcelos, A.C. Bernardes, C. Martins (2015) *ReNEP – The Portuguese Network of Continuously Operating Reference Stations: Status, Products and Services*. Presented at INSPIRE Geospatial World Forum, Lisbon, Portugal, 25-29 May 2015.
- M. Vasconcelos, P. Patrício, M. Caetano (2015) *iGEO: Na internet portal to access open spatial data in Portugal*. Presented at INSPIRE Geospatial World Forum, Lisbon, Portugal, 25-29 May 2015.

3 – LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL (NATIONAL LABORATORY OF CIVIL ENGINEERING)

3.1 – R&D PROJECTS IN THE DOMAIN OF APPLIED GEODESY

3.1.1 - Improving Methods of Applied Geodesy to the Observation of Engineering Works

This project is integrated in the Programmed Research Plan (*Plano de Investigação Programada – PIP*) of LNEC, and it includes a set of R&D activities developed with the aim of supporting the improvement and the updating of the important contribution provided, in a regular basis, by the Applied Geodesy Division (*Núcleo de Geodesia Aplicada – NGA*) to the monitoring of large engineering works (dams, bridges, etc.). The proposed project has a remarkable incidence in the engineering works observation activity, carried out in the Departments of Dams, Structures and Geotechnics. The geodetic observation activity plays an important role in the safety control of engineering works, and it demands a constant renewal of the measuring equipment, operative methods, and models for the observations processing, in order to offer a better accuracies and faster response times. The main purpose of this project consists on the study and improvement of the geodetic methods to the observation of large engineering works, essentially at two levels:

- i) Equipment for geodetic observation (including a GNSS permanent station and an EDM baseline test in LNEC campus).
- ii) Methods and models for the treatment of the observed data and quality evaluation of measurement and results.

3.1.2 - GNSS4SHM – GNSS and Accelerometers Data Fusion in Large Structures Monitoring (PTDC/ECM-EST/2131/2012)

This project had financial support by the *Fundação para a Ciência e Tecnologia* (FCT, Portuguese Foundation for the Science and Technology), during the period of 2013 – 2015.

Nowadays the safety control of large structures, such as concrete dams and bridges, tends to be based on automatic monitoring systems. These systems should be designed to automatically measure and analyze the main physical quantities that characterize the loads (static or dynamic) and the structural response, e.g. displacements, joint movements, strains and stresses, accelerations, natural frequencies, etc.

The implementation of automatic monitoring systems requires continuous updating, both in terms of equipment and software: equipment to measure, transmit, and store data, and software to support the automation process of gathering, processing, and analyzing. All the agents involved in the design, construction, management and safety control of large structures have come to recognize the interest of automatic monitoring systems. However, and despite its relatively low cost, their usage has not yet been generalized due to the fact that companies providing the equipment do not present full solutions that include all the software needed for automatic analysis of the gathered data and for automatically sending synthesized results to the technicians in charge of the structural safety control.

This project aims to develop a measurement system, based on GNSS, suitable to monitor large scale civil engineering structures, particularly bridges and dams. This monitoring system final objective is to measure the displacements of some selected points of these structures, points that should be the most important ones to characterize the general behaviour of the monitorized structure. The advantages of using a GNSS system are: the equipment is robust, it operates under all weather conditions, does not require intervisibility between the monitorized points and the reference points, uses an external tridimensional reference systems, and provides an extremely accurate time-reference frame. But GNSS positioning has the drawback of being affected by a numerous set of errors due to natural and artificial phenomena. There are well known observation and observation combination techniques (phase differences measurements, relative positioning, Precise Point Positioning, Real Time Kinematics) that allow to strongly reduce, or sometimes even eliminate, most of the errors.

The RTK (Real Time Kinematics) is the more recent high-precision positioning GNSS technique that allows obtaining high quality coordinates in almost real-time. When used in conjunction with top grade receivers (able to do observations at high frequencies) the RTK seems to be able to monitor high

frequencies displacements of structures. Unfortunately the positioning precision is only at the centimetre level. To improve the quality of the GNSS results at high frequencies it will be used techniques of data fusion of GNSS displacements with accelerations. The purpose of this fusion is to take advantage of the high precision achieved with GNSS, at low frequencies, and the great sensitivity of the accelerometers at high frequencies and to obtain a unified time series of displacements, with long duration and high resolution in time.

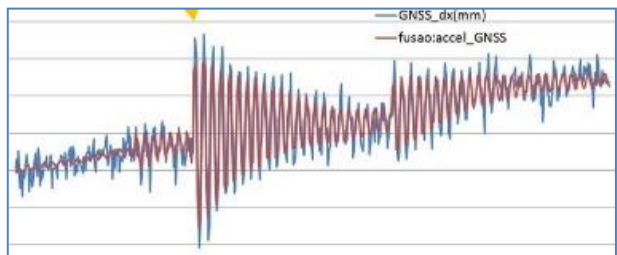
Tests and Applications

In order to accomplish the project goal some tests were already performed and two field applications will be implemented: Cabril dam (centre of Portugal) and Corgo viaduct (north of Portugal). Preliminary tests were done at LNEC in order to evaluate the potential and interest of data fusion for the analysis of displacements in large structures.

a) Tests at LNEC Campus



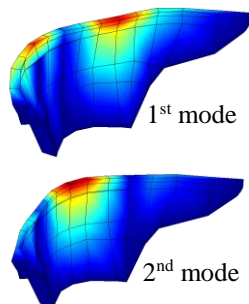
Three-storey building model developed at LNEC for studying the data fusion of GNSS displacements and accelerations (left image) Results: Overlapping of GNSS displacements (blue) with data fusion (red, GNSS displacements with Nanometrics accelerations). Above image.



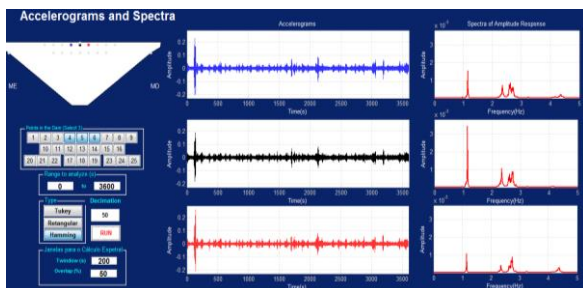
b) Cabril dam



Identified modes



The displacement history at the top of the central cantilever is proposed to be measured by GNSS. It is also proposed the development of the software **MoniDam**, for automatic online processing of data collected continuously by GNSS and accelerometers, allowing both the tracking of the time displacements evolution from GNSS and the tracking of the main modal parameters evolution – natural frequencies, mode shapes and modal damping.



MoniDam will be able to generate and send automatically, through the Internet, the most relevant structural information about dams' structural condition to the Owner and Safety Control Centers.

c) Corgo viaduct

A test was carried out in the Corgo viaduct in June 2013 during the viaduct load test. A GNSS Topcon receiver was mounted on the upper deck, at mid-span. A second GNSS Topcon receiver served as reference and was installed 1.7 km away from mid-span on the east bank of the viaduct.



Joint project between the Faculty of Engineering of the University of Porto (FEUP) and the LNEC, financed by the Foundation for Science and Technology (FCT)

3.2 – ORGANIZING SYMPOSIUM

3.2.1 - III Encontro Nacional de Geodesia Aplicada (3rd National Meeting of Applied Geodesy)

The Meeting was held October 18 – 19, 2012 in Lisbon, at Congress Centre of National Laboratory of Civil Engineering. The main purpose of this meeting was to join technicians, professors and researchers interested in different applications of the methods of the Geodesy.

The Meeting received more than 20 contributions on applications of Geodesy in several areas, namely: geodynamic studies, displacements monitoring of small and large structures such as dams or bridges, embankments, undergrounds or maritime works; conversion of data problems; processing and analysis of data.

The Meeting was attended by about 60 participants and more than 20 papers. Geotrilho, EDP, Leica Geosystem and Trimble sponsored the Meeting.

Scientific Committee

João Casaca (LNEC, Portugal), Chair;

António Tavares de Castro (LNEC, Portugal), Ana Fonseca (LNEC, Portugal), Maria João Henriques (LNEC, Portugal), José Nuno Lima (LNEC, Portugal), Sérgio Oliveira (LNEC, Portugal)

Organizing Committee

Maria João Henriques (LNEC, Portugal), José Nuno Lima (LNEC, Portugal).

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3.3 – PRESENTATIONS, ARTICLES AND OTHER R&D PUBLICATIONS IN THE DOMAIN OF APPLIED GEODESY

Technical and Scientific Journal

Casaca, J.; Henriques, M.J.. 2011. "Using Components of the Mahalanobis Squared Norm of the Residuals Vector for Quality Control in Local Engineering Networks", Survey Review 43, 321: 241 - 251. doi: 10.1179/003962611X13055561708218

Heleno,S. ; Oliveira,L. ; Henriques,M.J. ; Falcão,A.P. ; Lima,J.N ; Cooksley,G. ; Ferretti,A. ; Fonseca,A. ; Lobo-Ferreira, J.; Fonseca,J. . 2011. "Persistent Scatterers Interferometry Detects and Measures Ground Subsidence in Lisbon", Remote Sensing of Environment, 115: 2152 - 2167. doi: 10.1016/j.rse.2011.04.021

Lima, José Nuno & Casaca, João, 2012. "Smoothing GNSS Time Series with Asymmetric Moving Averages", Journal of Civil Engineering and Architecture, Vol. 6, Nº 6, June 2012, p. 745 – 750. ISSN: 1934-7359.

Conference and symposia proceedings

- Henriques, M.J. ; Ramos, P.. 2015.** "Thermal imaging of concrete dam surfaces to support the control of the evolution of pathologies ", Second International Dam World Conference, In Second International Dam World Conference Proceedings, Lisboa.
- Henriques, M.J. ; Roque, D. . 2015.** "Unmanned aerial vehicles (UAV) as a support to visual inspections of concrete dams ", Second International DAM WORLD Conference, In Second International DAM WORLD Conference Proceedings, Lisboa.
- Henriques, M.J. ; Braz, N. ; Roque, D. . 2015.** "Point Clouds and Orthomosaics from Photographs. Their Use in a Civil Engineering Laboratory. ", FIG Working Week 2015, In Proceedings of FIG Working Week 2015, Sofia.
- Lima, J.N.; Conde, V.; Candeias, H.. 2015.** " Quality assessment of GNSS with short-length session in the displacement measurement of a large embankment dam", Second International DAM WORLD Conference, In Second International DAM WORLD Conference Proceedings, Lisboa.
- Roque, D. ; Fonseca, A. ; Afonso, N. ; Henriques, M.J. ; Muralha, J. . 2015.** " Visual inspection aided by digital photography: application to the slopes of Foz Tua dam ", Second International DAM WORLD Conference, In Second International DAM WORLD Conference Proceedings, Lisboa.
- Roque, D. ; Perissin, D.; Falcão, A.P. ; Fonseca, A. ; Henriques, M.J. . 2015.** "Dam regional safety warning using time-series INSAR techniques", Second International Dam World Conference, In Second International Dam World Conference Proceedings, Lisboa.
- Roque, D. ; Perissin, D.; Falcão, A.P. ; Fonseca, A. ; Henriques, M.J. . 2015.** "Monitoring structure and regional-level displacements for Lisbon using multitemporal INSAR techniques", 9th International Workshop Fringe 2015 Advances in the Science and Applications of SAR Interferometry and Sentinel-1 InSAR Workshop, In 9th International Workshop Fringe 2015 Proceedings, Frascati.
- Henriques, M.J. ; Fonseca, A. ; Roque, D. ; Lima, J.N ; Marnoto, J. . 2014.** "Assessing the Quality of an UAV-based Orthomosaic and Surface Model of a Breakwater", FIG Congress 2014, In FIG Congress 2014, Kuala Lumpur.
- Henriques, M.J. ; Manta, V. ; Marnoto, J. . 2014.** "Avaliação da Qualidade Posicional. Aplicação a um Levantamento Realizado em Coimbra utilizando VANT", I Jornadas Lusófonas de Ciências e Tecnologias de Informação Geográfica, In Atas das I Jornadas Lusófonas de Ciências e Tecnologias de Informação Geográfica, Coimbra.
- Henriques, M.J. . 2014.** "Levantamento térmico de paramentos de barragens de betão para apoio ao acompanhamento da evolução de patologias ", Jornadas Portuguesas de Engenharia de Estruturas 2014, In Atas das Jornadas Portuguesas de Engenharia de Estruturas, Lisboa.
- Lima, J.N ; Oliveira, S. ; Henriques, M.J. . 2014.** "Fusão de deslocamentos medidos com o GNSS e de dados de acelerómetros medidos com elevada frequência de amostragem utilizando um filtro de Kalman", 8ª Assembleia Luso Espanhola de Geodesia e Geofísica, In 8ª Assembleia Luso Espanhola de Geodesia e Geofísica, Évora.
- Lima, J.N ; Oliveira, S. ; Henriques, M.J. ; Silvestre, A. . 2014.** "A integração do GNSS no controlo de segurança de grandes estruturas", Jornadas Portuguesas de Engenharia de Estruturas 2014, In Atas das Jornadas Portuguesas de Engenharia de Estruturas 2014, Lisboa.
- Pereira, M.P. ; Teodoro, A.C. ; Veloso-Gomes, F. ; Henriques, M.J. ; Lima, J.N ; Oliveira, S. . 2014.** "Port infrastructure monitoring (Madeira Island, Portugal) through GNSS, inertial systems and physical and numeric models", International Meeting on Marine Research 2014, In Atas do International Meeting on Marine Research 2014, Peniche.
- Roque, D. ; Fonseca, A. ; Henriques, M.J. ; Falcão, A.P. . 2014.** "A First Approach for Displacement Analysis in Lisbon Downtown Using PS-InSAR", SARWatch Workshop: Advances in the Science and Applications of SAR Interferometry, In Atas do SARWatch Workshop: Advances in the Science and Applications of SAR Interferometry, Troia.
doi: 10.1016/j.protcy.2014.10.094
- Henriques, M.J. ; Oliveira, S. ; Lima, J.N . 2013.** "Long-term geodetic displacements. Evaluating the quality of measured displacements", FIG Working Week 2013, In FIG Working Week 2013, Abuja.
- Lima, J.N ; Oliveira, S. ; Henriques, M.J. . 2013.** "Fusão de deslocamentos medidos com o GNSS e acelerações", 3º Congresso da Associação Portuguesa para a Segurança e Conservação de Pontes,

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In Actas do 3º Congresso da Associação Portuguesa para a Segurança e Conservação de Pontes, Porto.

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Henriques,M.J. ; Lima,J.N ; Oliveira,S. . 2012. "Measuring Inclinations in Cabril Dam with an Optoelectronic Sensor", FIG Working Week 2012, In FIG Working Week, Roma.

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4 – FACULDADE DE CIÊNCIAS DA UNIVERSIDADE DE LISBOA (FACULTY OF SCIENCES OF THE UNIVERSITY OF LISBOA)

4.1 – INTRODUCTION

In the last 4 years, the research of the group has been focused on the following topics:

- a) GNSS data processing and analysis for geodynamics studies,
- b) Improvement of Reference Frames,
- c) GPS and INSAR meteorology and (d) Ground deformation monitoring using radar interferometry.

4.2 - Publications in peer reviewed journals and/or other publications

- Mendes, V.B., J. Madeira, A. Brum da Silveira, A. Trota, P. Elosegui, J. Pagarete (2013). “Present-day deformation in São Jorge Island, Azores, from episodic GPS measurements (2001–2011)”, *Advances in Space Research*, Vol. 51, Issue 8, pp. 1581-1592, <http://dx.doi.org/10.1016/j.asr.2012.10.019>.
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- Marques, F.O., Catalão, J., Hildenbrand, A., Madureira, P., 2015. Groundmotion and tectonics in the Terceira Island: Tectonomagmatic interactions in an oceanic rift (Terceira Rift, Azores Triple Junction). *Tectonophysics* 651–652 (2015) 19–34, <http://dx.doi.org/10.1016/j.tecto.2015.02.026>.
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- Marques, FO, Catalão, J, DeMets, C., Costa, ACG, Hildenbrand, A., 2013. GPS and tectonic evidence for a diffuse plate boundary at the Azores triple Junction. *Earth and Planetary Science Letters* 381, 177-187, IF=4.349, Q1.
- Mateus, P., Nico, G., Tomé, R., Catalao, J., Miranda, P. M. A., 2013. Experimental Study on the Atmospheric Delay Based on GPS, SAR Interferometry, and Numerical Weather Model Data. *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 51, no. 1, January 2013, IF=3.467, Q1.
- Mateus, P.; Nico, G.; Catalao, J., 2013. Can spaceborne SAR interferometry be used to study the temporal evolution of PWV? *ATMOSPHERIC RESEARCH*, Volume: 119 Pages: 70-80 Published: JAN 2013. DOI: 10.1016/j.atmosres.2011.10.002, IF=2.200, Q2.
- Represas, P., Catalão, J., Montesinos, F. G., Madeira, J., Mata, J., Antunes, C. and Moreira, M., 2012. Constraints on the structure of Maio Island (Cape Verde) by a three-dimensional gravity model: imaging partially exhumed magma chambers. *Geophysical Journal International*, 190: 931–940. doi: 10.1111/j.1365-246X.2012.05536.x, IF=2.853, Q1.
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Catalão, J., G. Nico, R. Hanssen, C. Catita, 2011. Merging GPS and atmospherically corrected InSAR data to map 3D terrain displacement velocity. *IEEE Transactions on Geoscience and Remote Sensing*, Volume: 49, Issue: 6, Part: 2, 2354 – 2360, doi:10.1109/TGRS.2010.2091963, IF=3.467, Q1.

4.3 - Conference proceedings

- Silva, A.N., Taborda, R., Antunes, C., Catalão, J. and Duarte, J. 2013. Understanding the coastal variability at Norte beach, Portugal. *Journal of Coastal Research*, Special Issue No. 65, pp. 2173-2178, ISSN 0749-0208.201. IF=0.496, Q4.
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- Barros, B., Catita, C., Catalão, J., Barros, Z., 2014. Use of Satellite Images for Calculating Biomass in Eucalyptus Forest in the Municipality of Botucatu, Sao Paulo State, Brazil. *South-Eastern European Journal of Earth Observation And Geomatics*, Vol 3, No 2S, May 2014, Aristotle University of Thessaloniki, Greece, e-ISSN: 2241-1224
- Simões, D., Catalão, J., 2014. Navegação indoor baseada na rede WiFi como suporte a serviços baseados na localização: estudo de caso no Campus da UL. *I Jornadas Lusofonas de Ciências e Tecnologias de Informação Geográfica*, Coimbra, 11 a 13 Setembro 2014.
- Lopes, JAT, catalão, J., 2014. Generalização cartográfica de linhas recorrendo a técnicas de inteligência artificial. *I Jornadas Lusofonas de Ciências e Tecnologias de Informação Geográfica*, Coimbra, 11 a 13 Setembro 2014.
- Rilo Ana, Freire, P, Nogueira Mendes, R., Ceia, R., Catalão, J., Taborda, R., Melo, R., caçador, I., Conceição freitas, M., Fortunato, A., Alves, E., 2014. Metodologia para o traçado da Linha de Máxima Preia-Mar de Águas Vivas Equinociais em ambientes de transição: aplicação ao estuário do Tejo (Portugal)", *Revista de Gestão Costeira Integrada*, Vol. 14, N.1, 95-107. doi:10.5894/rgci450
- Travanca Lopes, J., Catalao, J., 2013. A new method for line generalization based on artificial intelligence algorithms. Edited by: Rocha, A; Reis, LP; Cota, MP; et al. Conference: 8th Iberian Conference on Information Systems and Technologies (CISTI) Location: Lisboa, PORTUGAL Date: JUN 19-22, 2013.
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- Oliveira, S.C.; Zêzere, J.L.; Catalão, J. (2013) - Contribuição da interferometria radar para a determinação do estado de actividade dos movimentos de vertente. *VI Congresso Nacional de Geomorfologia*. Coimbra 2013, Actas/Proceedings, Coimbra, p. 165-169. ISBN: 978-989-96462-4-7.
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- Jorge M, Vieira G, Catalão J., 2011. Detection of permafrost deformation at the Antarctic Peninsula using remote sensing: first insights from the South Shetland Islands. Proceedings of the III Iberian Conference of the International Permafrost Association, pp. 129-131.
- Catalão, J., Nico, G., Conde, V., 2011. Monitorização Da Estabilidade Vertical Da Cidade De Lisboa Usando Interferometria Radar. Cartografia e Geodesia 2011, Colégio Nacional de Engenharia Geográfica da Ordem dos Engenheiros, Actas da VII Conferência Nacional de Geodesia e Cartografia, Porto, 7 e 8 Maio de 2009, 73-81.

4.4 Conferences

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- Barbosa, S.M., V.B. Mendes (2012). "Nível do mar e movimento vertical no marégrafo de Cascais: análise de tendência." Actas das 2ª Jornadas de Engenharia Hidrográfica, Instituto Hidrográfico, Lisboa, 20-22 June 2012, pp. 155-157
- A.L.R. Sibrant, A. Hildenbrand, F.O. Marques, B. Weiss, T. Boulesteix, C. Hübscher, T. Lüdmann, A.C.G. Costa, J. Catalão, 2015. Large-scale sector collapses in S. Miguel Island, Azores. World Multidisciplinary Earth Science Symposium which take place the 7-11 september in Prague.
- Benevides, P., Catalão, J., Miranda. P., 2015. GPS tomographic experiment on water vapour dynamics in the troposphere over Lisbon. EGU General Assembly 2015, AS4.6, EGU2015-12862, Viena, Austria
- S. C. Oliveira, J. L. Zêzere, J. Catalão, G. Nico, 2013. The contribution of PSInSAR interferometry to landslide susceptibility assessment in weak rock-dominated areas. EGU General Assembly 2015, NH3.8, EGU2015-6140, Viena, Austria.
- A. R. Reis, J. Catalão, G. Vieira, G. Nico, 2015. Mitigation of atmospheric phase delay in InSAR time series using ERA-interim model and MODIS data: application to the permafrost deformation in Hurd peninsula, Antarctica. 9th International Workshop Fringe 2015 Advances in the Science and Applications of SAR Interferometry and Sentinel-1 InSAR Workshop, ESA, Frascati, Italy.
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- G. Nico, R. Lorusso, J. Catalão, FERRARA, F. Soccodato, A. Di Pasquale, 2015. Analysis of agricultural scenes based on SAR interferometry. 9th International Workshop Fringe 2015 Advances in the Science and Applications of SAR Interferometry and Sentinel-1 InSAR Workshop, ESA, Frascati, Italy.
- C. Pasquini, G. Nico, V. Ruggiero, J. Catalão, M. Mateus, 2015. A generalization of the SBAS approach to estimate the temporal evolution of Precipitable Water Vapour from time-series of InSAR interferograms. 9th International Workshop Fringe 2015 Advances in the Science and Applications of SAR Interferometry and Sentinel-1 InSAR Workshop, ESA, Frascati, Italy.
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- Lopes, JT, Catalão , J., 2014. Generalização cartográfica de linhas recorrendo a técnicas de inteligência artificial. I Jornadas Lusófonas de Ciências e Tecnologias de Informação Geográfica, Coimbra, 11 a 13 Setembro 2014.
- Simões, D. , Catalão, J., 2014. Navegação indoor baseada na rede WiFi como suporte a serviços baseados na localização: estudo de caso no Campus UL. I Jornadas Lusófonas de Ciências e Tecnologias de Informação Geográfica, Coimbra, 11 a 13 Setembro 2014.
- Mora, C., Vieira, G., Pina, P., Catalão, J., 2014. Detailed mapping of snow cover as a contribution for identifying ground thermal regimes in high cloudiness Polar environments. Results from C and X-band microwave imagery in the South Shetlands /Antarctica). Book of Abstracts of EUCOP4 – 4th European Conference on Permafrost, 18-21 June, 2014, Évora, Portugal.

**INTERNATIONAL ASSOCIATION OF GEODESY
NATIONAL REPORT OF PORTUGAL**

- Vieira, G., Catalão, J., Prates, G., Correia, A., 2014. Monitoring the surface deformation of Hurd rockglacier using D-GPS measurements and D-InSAR: first results (Livingston Island, Antarctica). Book of Abstracts of EUCOP4 – 4th European Conference on Permafrost, 18-21 June, 2014, Évora, Portugal.
- Prates, G., Vieira, G., Catalão, J., Francelino, M., 2014. Assessment of photogrammetric techniques for rock-glacier creep monitoring (South Shetlands, Antarctica). Book of Abstracts of EUCOP4 – 4th European Conference on Permafrost, 18-21 June, 2014, Évora, Portugal.
- Manuel, J., Catalão, J., Vieira, G., 2014. InSAR analysis of surface displacement of rock glaciers (South Shetlands, Antarctica). EUCOP4, European Conference on Permafrost, 18-21 June, 2014, Évora, Portugal.
- Catalão, J., Mateus, P., Nico, G., 2014. On the possibility of using SAR interferometry to map the atmosphere precipitable water vapour. Copernicus User Awareness & Training Event, GIO Lot2 User Uptake project funded by EC, Lisbon 13 e 14 Fevereiro 2014.
- Vieira, G., Catalão, J., Prates, G., Correia, A., 2014. Monitoring the surface deformation of Hurd rockglacier using D-GPS measurements and D-INSAR: first results (Livingston Island, Antarctica). Geophysical Research Abstracts, Vol. 16, EGU2014, 2014. EGU General Assembly 2014.
- Fonseca, A., Catalão, J., Zêzere, J.L., Madeira, J., Bouchta, E.F., 2013. Identification of active deep-seated landslides in the Central Rif Mountains through Persistent Scatterer Interferometry, Hotspot and Cluster analysis. ESA Living Planet 2013.
- Piernicola Lollino, Catalão, J., Nico, G., Conde, V., 2013. Numerical modelling of ground subsidence in the city of Lisbon. Geophysical Research Abstracts, Vol. 15, NH3.13, EGU2013-13966, 2013, EGU General Assembly 2013.
- A.C.G. Costa, A. Hildenbrand, F.O. Marques, A.L.R. Sibrant, J. Catalão, C.M.S. Catita, 2012. Tectonic and geomorphologic evolution of an active large-scale slump (Pico Island, Azores). IAG International Conference in Geomorphology – 2013.
- Rolim, J., Teixeira, J., Catalão, J., 2012. Irrigation management of crops rotations in a changing climate, European Geosciences Union, General Assembly 2012, Viena, Austria, 22 a 27 Abril 2012.
- Catalão, J., Catita, C., Marques, F.O., Costa, A.G., Hildenbrand, A., 2012. Deformation of Faial, Azores, as revealed by GPS and INSAR measurements in the period 2001-2011. 7th Portuguese-Spanish Assembly of Geodesy and Geophysics, 25-28th June 2012. San Sebastian, Spain.
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- Freire, P., Rilo, A. R., Ceia, R., Mendes, R. N., Catalão, J., Taborda, R., Mendes, R., 2012. Tipificação das zonas marginais estuarinas. O caso do estuário do Tejo. 2^{as} Jornadas de Engenharia Hidrográfica, 20-22 de junho 2012.
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- Jorge M, Catalão J, Vieira G., 2011. Periglacial Mass Wasting in the Antarctic Peninsula: Displacement detection at the South Shetlands Islands with DInSAR. Fringe 2011 Workshop, 19-23 September 2011, ESRIN, Frascati, Italy.
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4.5 - Research contracts with national or international entities

2011/13 Mapping Vertical Land Movement and Coastline Retreat Study using INSAR and GNSS. Projecto financiado pela National University of Singapore, Singapura. Contracto de 30000 euros, IDL, UL.

2013/15 Permantar and Climate Change in the Antarctic Peninsula. PTDC/AAG-GLO/3908/2012. Contribuição na componente Detecção Remota (InSAR deformation).

2012/15 SMOG - Structure of Moist convection in high-resolution GNSS observations and models. PTDC/CTE-ATM/119922/2010. Contribuição na Tomografia GNSS 4D.

2011/13 Evaluation of climate changes impacts on irrigated systems and definition of adaptation measures. FCT-PTDC/AAC-AMB/113639/2009. Contribuição no projecto de SIG.

2010/12 MorFeed - Morphodynamic feedback of estuarine margins to climate change. FCT-PTDC/AAC-AMB/100092/2008. Contribuição na evolução das margens do estuário do Tejo usando imagens Landsat e e sensores SAR.

2010/12 MEGAHAZARDS, Mass-wasting episodes in the geological evolution of the Azores islands: timing, recurrence, mechanisms, and consequences (MEGA hazards). FCT-PTDC/CTE-GIX/108149/2008. Contribuição na medição da deformação nas ilhas do Pico e Faial com recurso a INSAR e GPS.

5 – OBSERVATÓRIO ASTRONÓMICO PROF. MANUEL DE BARROS DA UNIVERSIDADE DO PORTO (ASTRONOMICAL OBSERVATORY PROF. MANUEL DE BARROS OF THE UNIVERSITY OF PORTO)

5.1 – MAIN ACTIVITIES IN 2011-2015

Airborne gravimetry – implementation of strapdown systems (hardware integration and software development) using different IMUs grades.

Mobile Mapping Systems - implementation of MMS systems for coastal monitoring integrating different sensors and using different terrestrial and aerial platforms (light airplanes and UAVs)

Buoys positioning for studies of ocean dynamics and sea level monitoring.

5.2 – PROJECTS (2011-2015)

- RAIA.co - Ocean Observatory of the Iberian Margin and Littoral RAIA (Interreg)
- RAIA_TEC – Marine Technology and Information (Interreg)
- PITVANT - Unmanned Air Vehicles development program (Portuguese Department of Defense)
- ECORISK - Ecological risk assessment of oils and hazardous and noxious substances in the NW Portuguese coast (SR&TD Integrated Program MARVALOR)
- GNSS4SHM - Integração de dados GNSS e de acelerómetros na monitorização de grandes estruturas (PTDC/ECM-EST/2131/2012)
- RAIA - Ocean Observatory of the Iberian Margin (Interreg)
- DEOSOM - Detection and Evaluation of Oil Spills by Optical Methods (AMPERA ERA-NET)
- FlexiMap3D - Flexible Kinematic System for Mapping through 3D Images (ADI- QREN)

5.3 – SOME RECENT PUBLICATIONS (2011-2015)

AYRES-SAMPAIO, D., DEURLOO, R., BOS, MS, MAGALHÃES, A., BASTOS, L. 2015. A comparison between three IMUs for strapdown airborne gravimetry. *Surveys in Geophysics*. DOI 10.1007/s10712-015-9323-5.

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