

PORTUGAL

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

**INTERNATIONAL ASSOCIATION OF GEODESY
IAG**

NATIONAL REPORT

2003 – 2006

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

HOLD AT PERUGIA, 2 – 13 JULY 2007

Coordinated by

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

1 – INTRODUCTION

The present report contains the information about the work carried out in Portugal in the field of Geodesy, covering the period 2003-2006.

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

- *Instituto Geográfico Português* (Portuguese Geographic Institute) - report by Eng. Maria Helena Kol;
- *Instituto de Investigação Científica Tropical* (Tropical Science Research Institute) - report by Dr. Paula Santos;
- *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;
- *Centro de Investigação em Ciências Geo-espaciais e Departamento de Matemática Aplicada da Faculdade de Ciências da Universidade do Porto* (Geo-Space Sciences Research Center and Department of Applied Mathematics of the Faculty of Sciences of the University of Porto) – report by Prof. José Pereira Osório;
- *Observatório Astronómico Prof. Manuel de Barros da Universidade do Porto* (Astronomical Observatory Prof. Manuel de Barros of the University of Porto) – report by Dr. Luisa Bastos.

It must also be mentioned the personal contribution to the work within the IAG structure, namely:

- João Agria Torres (*SPUIAGG*) as President of EUREF, the Regional Reference Frame Sub-commission for Europe of Commission 1 – Reference Frames.

2 – INSTITUTO GEOGRÁFICO PORTUGUÊS

2.1 – INTRODUCTION

The Instituto Geográfico Português (IGP) is an organism created in 2002, resultant of the union of the former Portuguese Institute of Cartography and Cadastre and the former Portuguese Centre for Geographical Information.

IGP is the organisation responsible for the establishment and maintenance of the national geodetic reference frames. In its works are included:

- geodetic network;
- high precision levelling;
- tide gauges;
- gravimetric network;
- vertical deflection points’;
- GPS permanent network;
- calibration baselines.

2.2 – POSITIONING

2.2.1 – Geodetic Network - Mainland

In 2004 the observation with GPS of the second order network in Portugal mainland was completed. The following standards were used to observe the 2nd order network:

- 4-5 double frequency GPS receivers;
- 2 hours sessions;
- 15 seconds epoch interval;
- 10 degrees elevation mask;
- occupation of two 1st order points in each session.

The figure 1 shows the trig points of the mainland network already observed with GPS.

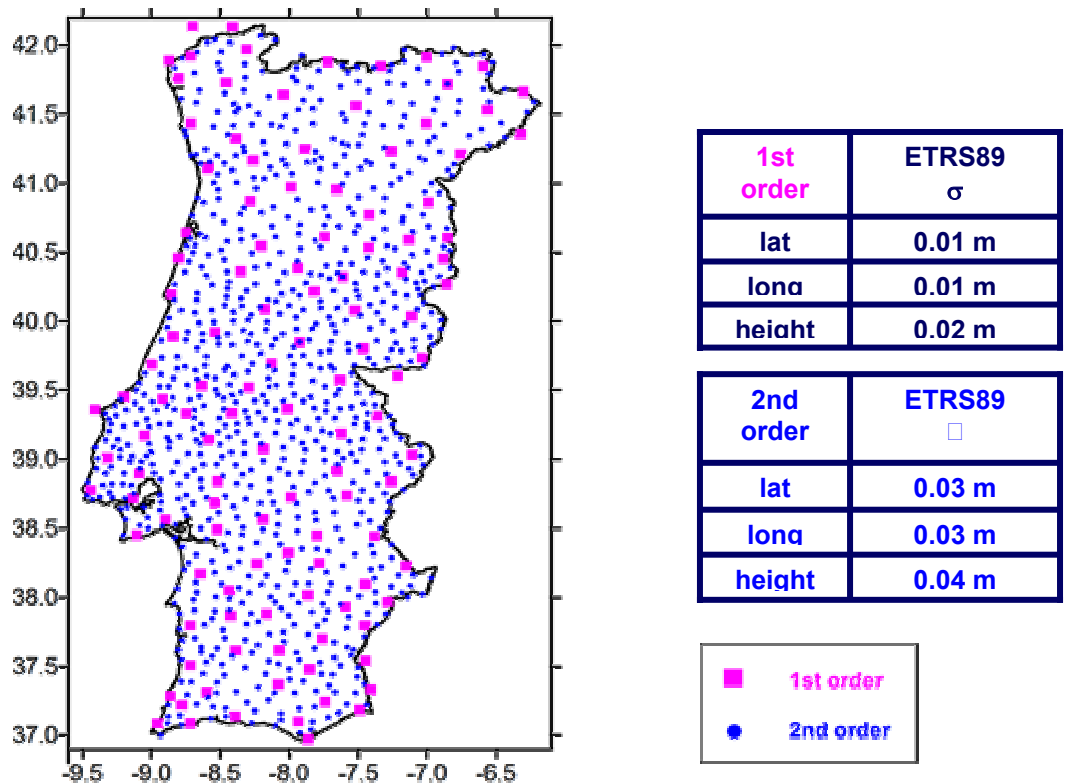


Figure 1 – Mainland Geodetic network observed with GPS until the end of 2004.

2.2.2 – Geodetic Network - Madeira

The Geodetic network of Porto Santo island, in Madeira Archipelago - figure 2 - was measured with GPS during October 2004. A total of twenty monumental geodetic points defines the Porto Santo network. This field campaign also includes the realization of reciprocals and simultaneous zenithal observations to improve precision in the height. The preliminary computation shows results (for ITRF93) better than 2 centimetres (at 95% of confidence level) for the coordinates. Local Datum (Base SE) coordinates were also computed, using the same set of observations. The Geodetic Network has already been adjusted for Base SE coordinates, with the same precision as the ITRF93 coordinates.

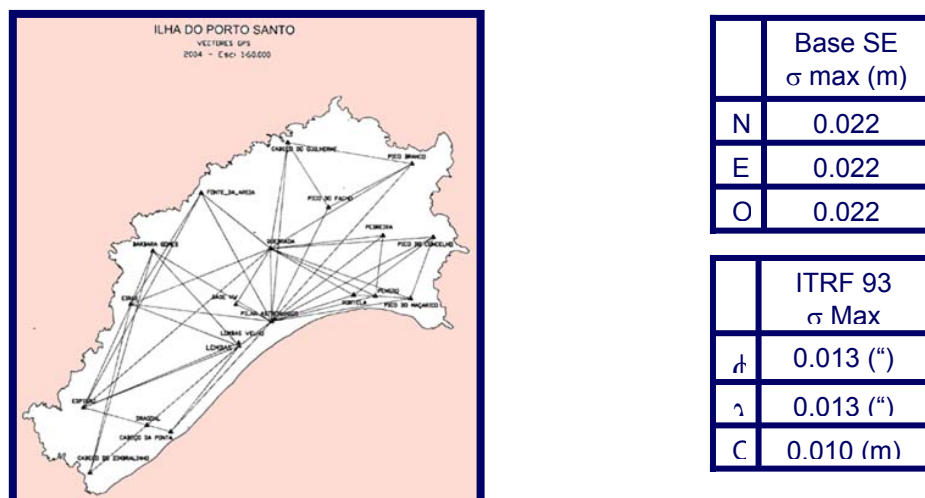


Figure 2 – Porto Santo Island Geodetic network observed with GPS.

2.2.3 – Geodetic Network - Azores

The Geodetic network of Corvo and Flores islands, in Azores Archipelago - figure 3 - was measured with GPS during July 2005. A total of six monumental geodetic points defines the Corvo network and a total of thirty three monumental geodetic points defines the Flores network. The preliminary computation shows results (for ITRF93) better than 4 centimetres in Corvo and 2 centimetres for the coordinates of Flores (at 95% of confidence level). Local Datum (Observatório) coordinates were also computed, using the same set of observations.

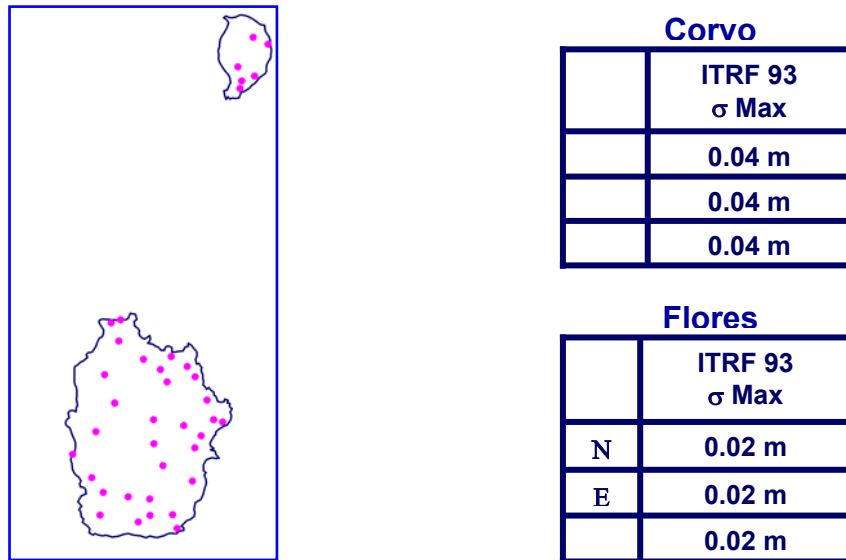
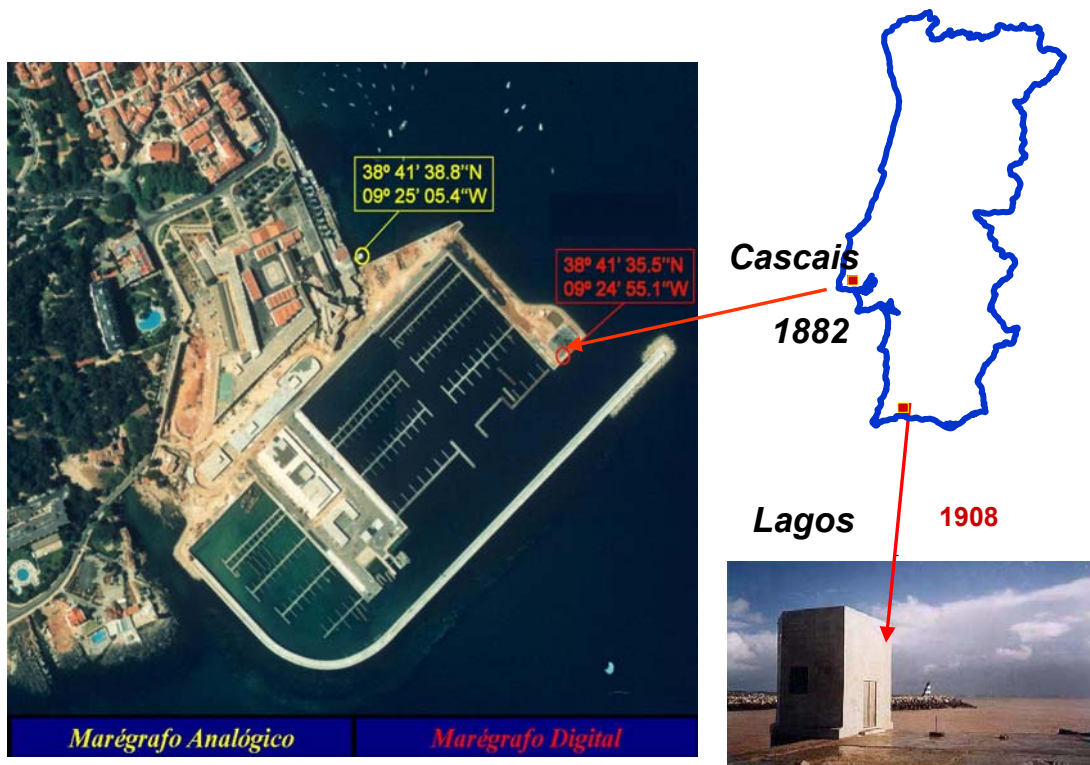


Figure 3 – Corvo and Flores Islands Geodetic network observed with GPS.

2.3 – Tides Gauges

IGP is responsible for two floating tide gauges, at Cascais and Lagos, working since 1882 and 1908, respectively. The Cascais tide gauge is the reference for the mainland ordnance datum.



In 2003, due to the technological innovations and for a better service to the scientific community, IGP acquired 2 new acoustic tide gauges, in order to replace the floating tide gauges systems. These new systems will work simultaneously with the older ones for at least one year. In that way we assure a better quality of the data and also the continuity of the secular series.



2.4 – Vertical Deflection Points’ Network

A network of about 130 vertical deflection points’ was observed with a prismatic astrolabe and a Wild T4 theodolite until mid 1980s.

In 1998 a project for the re-observation and densification of this network was started in a co-operation with ETH-Zürich (Swiss Federal Institute of Technology Zurich). The first work was the re-observation of 25 stations with the Zenithal Camera of ETH-Zürich. In the subsequent year another 28 points were observed with the ICARUS automatic system.

In 2000, following a protocol between IGP and FCUL, a special densification campaign along the central part of Portugal was launched. During this campaign the ICARUS system has been put in operation together with a GPS Palissade receiver, for timing purposes. In the year 2001 another 11 stations were observed.

In 2004 in field campaign performed by Dr. Beat Bürki and Dr. Anna Müller of ETH in cooperation with IGP, 17 points were measured with the new digital Zenith Camera system DIADEM.

Figure 4 shows the distribution of the vertical deflection points’ network and the methods of observation. The stations related with the FCUL specific work are not indicated.

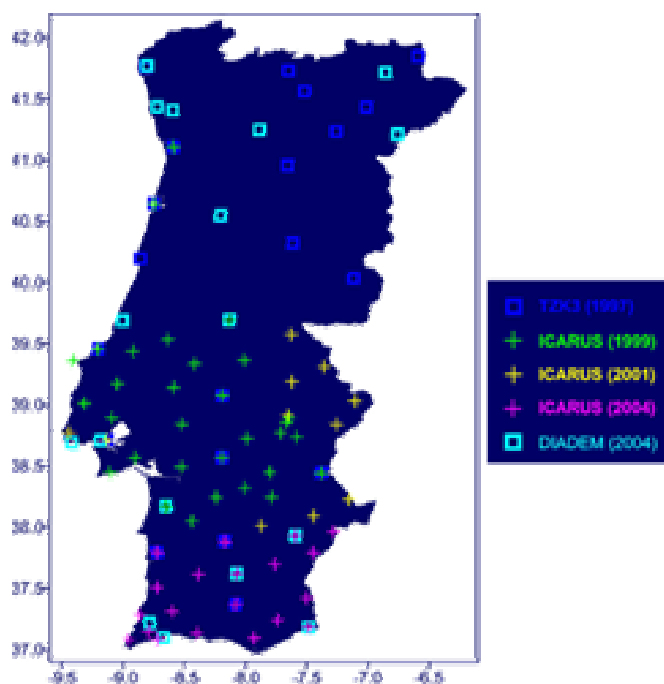


Figure 4 – Astronomical observations in Portugal Mainland.

2.5 – GPS Permanent Network

The first GPS permanent station was installed in 1997 in Cascais near the tide gauge. In the beginning of 2000 three more stations started to work: two near the tide gauges of Lagos and Leixões, and the other in Ponta Delgada, Azores. All these 4 stations are included in the EUREF GPS Permanent Network. The Ponta Delgada station also belongs to the International GPS Service Network.

The project of the GPS permanent network continued in the subsequent years with the installation of 5 other stations: Beja and Mirandela in 2001, Melriça and Funchal (Madeira Archipelago) in 2002, IGP in 2006. The configuration of the present GPS permanent network is shown in figure 5.

All the data regarding these 9 stations can be obtained at the anonymous ftp of IGP: <ftp://ftp.igeo.pt/pub/gpsdata/>.



Figure 5 – GPS Permanent Network.

2.6 – DETERMINATION OF THE GRAVITY FIELD

2.6.1 – Gravimetric Network

The gravimetric network of Portugal mainland consists of more than 6500 points, measured with LaCoste & Romberg relative gravimeters, and has a density of about one point per 25 km². In 1994 Dr. J. Mäkinen of the Finnish Geodetic Institute (FGI) had determined the absolute value of gravity in Gaia and Mértola, with the JILAg-5 absolute gravity meter.

In 2003 Dr. Mäkinen came again to Portugal to perform an absolute gravity survey, this time with FGI's new FG5 #221 absolute gravimeter. The Gaia and Mértola stations were re-measured, and a new point was measured in Cascais, in the same building of the GPS permanent station and near the tide gauge. The present state of the gravimetric network is shown in figure 6.

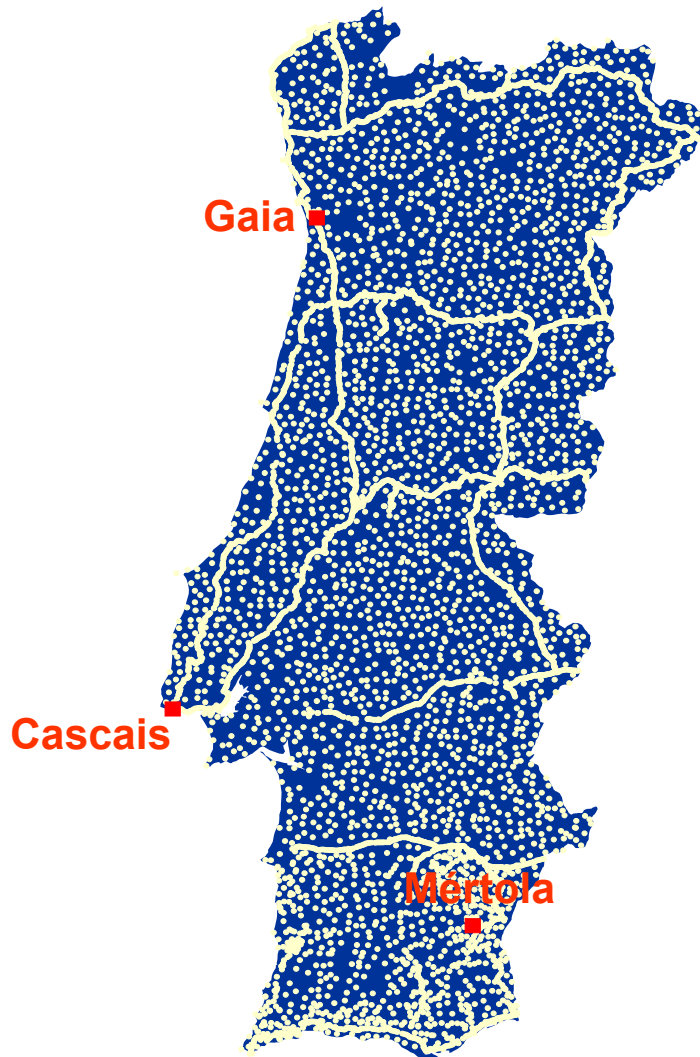


Figure 6 – Gravimetric network of Portugal mainland.

2.6.2 – Geoid Model - GPS on Levelling Bench Marks

In a joint project of IGP, FCUL and the Instituto de Astronomía y Geodesia de la Universidad Complutense de Madrid (Spain), a new gravimetric geoid model was developed. The first results were first presented at the 3rd Hispano-Portuguese Assembly of Geodesy and Geophysics, held in Spain in 2002.

In 2006, IGP promoted a GPS campaign with observations on 80 levelling bench marks, to complete the full coverage of the country, since that only exists 26 measurements. The main goal of this project was to adjust and validate the Portuguese gravimetric geoid model and also to contribute to the EUVN_DA project.

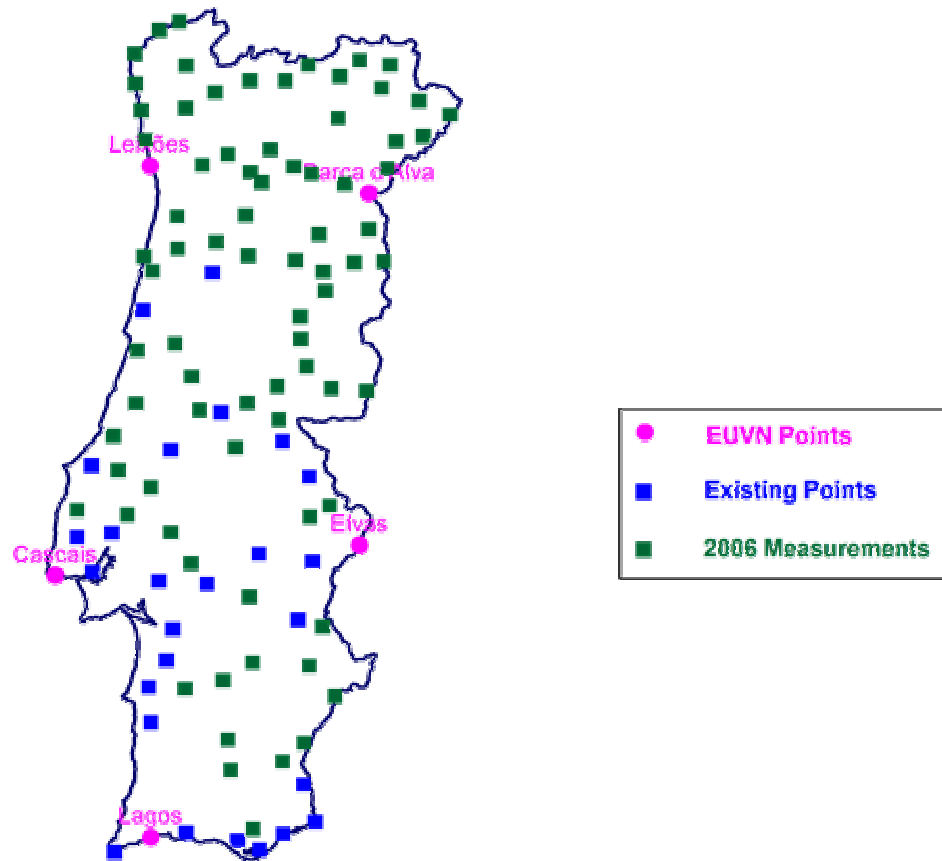


Figure 7 – GPS on levelling bench marks in Portugal mainland

2.7 – HUMAN AND MATERIAL RESOURCES

The human resources of the Department of Geodesy of IGP are five surveying engineers and six surveying technicians. The equipment consists on:

- 2 LaCoste & Romberg, model G gravimeters;
- several dual-frequency GPS receivers;
- several geodetic levels;
- several optical-mechanics theodolites (astronomy, geodesy and surveying);
- several computers;
- Bernese GPS software;
- GPS software;
- gravimetry adjustment and computation software;
- triangulation adjustment and computation software;
- levelling adjustment and computation software;
- geodetic astronomy adjustment and computation software;

2.8 – PUBLICATIONS

- Kol, H., Vasconcelos, M., Botelho, H. - **Rede Nacional de Estações GNSS de observação Contínua – Um projecto ao serviço de cidadão**. Comunicação realizada no ESIG 2006 - IX Encontro de utilizadores de informação geográfica, Oeiras, Portugal, 15 a 17 de Novembro de 2006.
- Silva, A, Crisóstomo, G., Freire, E., Costa, F. - **Reflexões sobre a variação do Nível do Mar em Portugal**, 1ª Conferência Lusófona sobre o Sistema Terra, Lisboa, 22-24 de Março de 2006.
- Crisóstomo, G., Kol, M. H., Vasconcelos, M. – **Marégrafos do IGP - Acústicos vs. Analógicos**, IV Conferência Nacional de Cartografia e Geodesia, Lisboa, Março 2005.
- Catalão, J., Kol, M. H., Sevilla, M. J., Anes, J. – **IAGM04 - Geóide Centimétrico no Atlântico Nordeste (Ibéria – Açores)**, IV Conferência Nacional de Cartografia e Geodesia, Lisboa, Março 2005.
- Vasconcelos, M., Casaca, J. - **A Transformação de Coordenadas Geodésicas entre o Datum 73 e o ETRS89 por Predição Espacial**, IV Conferência Nacional de Cartografia e Geodesia, Lisboa, Março 2005.
- Vasconcelos, M., Martins, C., - **Rede Geodésica Nacional: Estado Actual; Competências; Informação de Cidadania**, GisPlanet 2005, Lisboa, Portugal.
- Crisóstomo, G., Vasconcelos, M., Kol, H. – **Novo Sistema de Aquisição de dados Maregráficos do IGP**, Resumos da 4ª Assembleia Luso Espanhola de Geodesia e Geofísica, Figueira da Foz, Fevereiro 2004.
- Ribeiro, H., Martins, C., - **Automatização das Estações Permanentes GPS do IGP**, Resumos da 4ª Assembleia Luso Espanhola de Geodesia e Geofísica, Figueira da Foz, Fevereiro 2004.
- Martins, C., Ribeiro, H., - **Observação da Rede Geodésica de 2ª Ordem com GPS**, Resumos da 4ª Assembleia Luso Espanhola de Geodesia e Geofísica, Figueira da Foz, Fevereiro 2004.
- Vasconcelos, M., Casaca, J. - **Análise Estatística das Coordenadas da Rede Geodésica Portuguesa**, Resumos da 4ª Assembleia Luso-Espanhola de Geodesia e Geofísica, Figueira da Foz, Fevereiro 2004.
- Gonçalo C. Crisóstomo, Kol, H., Vasconcelos, M., - **Referencial Altimétrico Nacional**, XXI Assembleia DIGSA, Lisboa, 22-26 de Novembro de 2004.
- Vasconcelos, M., Casaca, J., - **Using Residuals for Improving the Accuracy of Coordinate Transformation**, Simpósio EUREF 2004, Bratislava, Eslováquia, 2 a 5 de Junho de 2004. (a publicar).

3 – INSTITUTO DE INVESTIGAÇÃO CIENTÍFICA TROPICAL

3.1 – INTRODUCTION

The origin of the Tropical Science Research Institute (IICT) dates from 1883 when a “Cartography Commission” was created to promote the scientific study of the ancient Portuguese colonies in Africa and to establish the basis for their scientific occupation. It was the first Portuguese institution devoted, in a permanent way, to develop scientific research in the tropics.

Geodesy is one of the scientific areas covered by the activities of IICT. The geodetic work in Africa (Angola, Mozambique, etc.) and in Asia was started more than 100 years ago. A systematic and well-organized acquisition of geodetic data on the ground and its adequate mathematical treatment has been carried out for many decades.

3.2 – RESEARCH & DEVELOPMENT PROJECTS

3.2.1 – Geodetic Network of Mozambique

This project has three main objectives. The first one is to update the classical geodetic triangulation of Mozambique with GPS. The second is to conclude two lines of the geometric levelling network of Mozambique. The third objective is to develop research studies with all geodetic data from the ex-Missão Geográfica de Moçambique.

Activities:

- Integration of the GPS observations in Mozambique Geodetic Network;
- Digitalisation of geodetic data field books to build a digital database.
- Adjustment of the classical terrestrial network of Mozambique in ITRF

3.2.2 – Geodetic Network of Angola

The objective of this project is the development of research studies with all geodetic data from the ex-Missão Geográfica de Angola

Activities:

- Observation of Luanda network with GPS
- Estimation of Bursa –Wolf parameters between Camacupa datum and ITRF for Luanda

3.3 – HUMAN AND MATERIAL RESOURCES

The human resources are two Researchers (PhD equivalent) .

The equipment consists on:

- 3 dual-frequency GPS receivers (Trimble 4000).
- 1 C/A code GPS receiver (Trimble Pathfinder Pro XL).
- 1 Gravimeter LaCoste & Romberg G.
- 2 Theodolite Total Stations
- Several optical-mechanics theodolites (Astronomy, Geodesy and Surveying)
- Several Geodetic Levels.
- 1 Portable Computer
- Several Pentium Computers
- Bernese GPS Software Version 4.2
- GPSurvey Software (Trimble)
- Gravimetry Adjustment and Computation Software (LaCoste & Romberg)
- Gravimetry Adjustment and Computation Software (Finnish Geodetic Institute)
- Triangulation Adjustment and Computation Software
- Levelling Adjustment and Computation Software
- 1 Calcomp Plotter
- 1 Desk Scanner

3.4 – PUBLICATIONS

- Faria, B.V.E., Fonseca, J.F.B.D., Heno, S.I.N, Lázaro, Clara, d'Oreye, N. ,Ferreira, Barros, I.Santos, P., bandomo, Z, day, S.J., Osório J. PBaio, M., Matos, J. L** “Multi-parameter monitoring of Fogo island , Cape Verde” . Journal of Volcanology and Geotthermal Research. 2003, 125 , p 39 – 56.
- Lázaro, Clara, Santos, Paula, Lima, J.Nuno, Heleno, Sandra N., Barros, Inocêncio, Matos João, Baio, Miguel, Fonseca , João F.B.D.–** “Detection of subsurface magma movements in Fogo Volcano, Cape Verde, trough Microgravity observations. Proceedings of III Assembleia Luso-Espanhola de Geodesia e Geofísica, Valencia, Spain, 2003. tomo II, pp 720-722
- Lima, J.N., Heleno, S.I.N., Fonseca, J.F.B.D.,** - “Establishment of a GPS control network in FogoVolcano, Cape Verde”. Proceedings of III Assembleia Luso-Espanhola de Geodesia e Geofísica, Valencia, Spain, 2003. tomo I pp 114-117
- Lima, J.N., Lazaro, C., Santos, P., Heleno, S.I.N., Fonseca, J.F.B.D.,** - “GPS and microgravimetry for Fogo Island volcano control”. Proceedings of III Assembleia Luso-Espanhola de Geodesia e Geofísica, Valencia, Spain, 2003. tomo I pp 297-300
- Lima, J.N.–** “O GPS na observação geodésica de Barragens – Resultados do 1º ensaio”. Laboratório Nacional de Engenharia Civil, Relatório 157/05 - NGA/DBB, Lisboa 2005
- Lima, J.N.–Henriques, Maria João, casaca, João –** “ Monitorização de estruturas com GPS”. Livro das actas da IV conferência Nacional de Cartografia e Geodesia, Lisboa 2005, Cartografia e Geodesia 2005, Lidel pp 597-605.
- Lima,J.N., Casaca,J., Henriques,M.J. –** “Accuracy of Displacement Monitoring at Large Dams with GPS”. Presented at the International Symposium on Geodetic Deformation Monitoring: From Geophysical to Engineering Roles, Jaen, 2005, International Association of Geodesy Symposia, Vol. 131, Springer-Verlag Berlin Heidelberg 2006, pp 239 – 243.
- Lima, Nuno, Santos, Paula e Barros, F. Frias de -** Instrumentos Geodésicos e Astronómicos utilizados nas Antigas Missões Geográficas, “O Domínio da Distância”, Comunicação e Cartografia, IICT 2006, pp 165 – 170.
- Santos, Paula, Lima, J.N. –** “Observação do troço Buzi-Zimuala com GPS para a conclusão do ajustamento da Rede Geodésica de Moçambique” Livro das actas da IV conferência Nacional de Cartografia e Geodesia, Lisboa 2005, Cartografia e Geodesia 2005, Lidel pp 587-596.
- Santos, Paula, Lima, J.N., Quembo, J.L. –** “Adjustment of the Classical Terrestrial Geodetic Network of Mozambique tied to ITRF”, 5th FIG Regional Conference for Africa - Accra, Ghana, March 2006 (<http://www.fig.net/accra/>).
- Santos, Paula, Lima, Nuno e Barros, F. Frias de -** Atribuições das Missões Geográficas instituídas pela Comissão de Cartografia, “O Domínio da Distância”, Comunicação e Cartografia, IICT 2006, pp 171 – 189.
- Santos, Paula, Barros, Frias de e Lima, Nuno -** Catálogo dos Teodolitos usados nas Missões Geográficas da antiga Comissão de Cartografia, “Comissão de Cartografia - Catálogos”, IICT 2006, pp 3 – 27.

4 – LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

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

Project: Geodesy Applied to the Observation of Engineering Works.

Abstract: The project, integrated in the Programmed Research Plan (Plano de Investigação Programada - PIP) of LNEC, 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 Centre (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 observation of engineering works, that doesn't exempt a constant renewal of the measuring equipment, operative methods, and methods and models for the treatment of the observations. The central 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) equipments for geodetic observation (including a GNSS permanent station and multi-pillar baseline in LNEC campus)
- ii) methods and models for the treatment of the observed data and quality evaluation of measurements and results.

4.2 – ORGANIZING A IAG/FIG SIMPOSIUM

LNEC and the “Local Organizing Committee” are organizing the symposium “Measuring the Changes”, to be held in Lisbon, Portugal, from 12 to 15 May 2008 at LNEC Congress Center. “Measuring the Changes” (<http://measuringchanges.lnec.pt>) is integrated in the activities of IAG and FIG and combines the 4th IAG Symposium on Geodesy for Geotechnical and Structural Engineering with the 13th FIG Symposium on Deformation Measurements and Analysis.

The symposium will consist of both oral and poster presentations in three days, plus a one-day technical tour. The topics include Monitoring Static and Dynamic Deformations of Engineering and Geotechnical Structures, Multi-Sensor Systems, Automation of Monitoring and Warning Systems and Applications in Geotechnical, Structural Engineering and in Geosciences at Local and Regional Scales.

Local Organizing Committee of “MEASURING THE CHANGES”

Maria João Henriques – President (LNEC)
Rui Manuel Fernandes (UBI)
José Nuno Lima (LNEC)
João Agria Torres (SPUIAGG)
Manuela Vasconcelos (IGP)

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

Henriques,M.J., Casaca,J. – Monitoring Displacements at Large Dams by Means of Precision Traverses. Presented in FIG Working Week 2003, Paris, 2003.

Henriques,M.J., Casaca,J.– Quality Control of a Large Dam Geodetic Monitoring System. Presented in 1st FIG International Symposium on Engineering Surveys for Construction Works and Structural Engineering. Nottingham, 2004.

Casaca,J., Henriques,M.J. – Geodesia Aplicada à Monitorização de Barragens. Presented at the 4ª Assembleia Luso Espanhola de Geodesia e Geofísica, Figueira da Foz, 2004.

Casaca,J., Henriques,M.J. – O Princípio de Fermat e a Refracção Vertical. Presented at the Congresso de Métodos Computacionais em Engenharia, Lisboa, 2004.

Henriques,M.J., Santos,R., Silva,A., Coelho,J. – A Ambientação de Equipamento de Observação Geodésica. Presented at the IV Conferência Nacional de Cartografia e Geodesia. Lisboa, 2005.

Henriques,M.J., Casaca,J. – A Importância do Quadro de Referência nos Sistemas de Observação Geodésica de Grandes Barragens. Presented at the IV Conferência Nacional de Cartografia e Geodesia, Lisboa, 2005.

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

- Lima,J.N., Henriques,M.J., Casaca,J.** – Monitorização Geodésica de Estruturas com o GPS. Presented at the IV Conferência Nacional de Cartografia e Geodesia, Lisboa, 2005.
- Casaca,J., Henriques,M.J.** – The Impact of Vertical Refraction at Local Three-dimensional Engineering Control Networks. Presented at the International Symposium on Geodetic Deformation Monitoring: From Geophysical to Engineering Roles, Jaen, 2005.
- Lima,J.N., Casaca,J., Henriques,M.J.** – Accuracy of Displacement Monitoring at Large Dams with GPS. Presented at the International Symposium on Geodetic Deformation Monitoring: From Geophysical to Engineering Roles, Jaen, 2005.
- Casaca,J., Henriques,M.J.; Fonseca,A.M., Lima,J.N.,** – A Geodesia Aplicada à Medição de Deslocamentos em Grandes Barragens. Presented at the Seminário: Barragens - Tecnologia, Segurança e Interação com a Sociedade, Lisboa, 2005.
- Caldeira,L., Casaca,J., Serra,J.B., Henriques,M.J., Lima,J.N.** – A Utilização do GPS em Sistemas de Aviso e Alerta em Grandes Barragens de Aterro. Presented at the XIII Congresso Brasileiro de Mecânica dos Solos e Engenharia Geotécnica, Curitiba, 2006.
- Lima,J.N., Henriques,M.J., Casaca,J., Coelho,J.** - Medição de Deslocamentos Superficiais em Barragens de Aterro com o GNSS - Presented at the 4as Jornadas Portuguesas de Engenharia de Estruturas, Lisboa, 2006.
- Casaca,J., Henriques,M.J.** – Uncertainty in Convergence Measurements made by Motorized Tacheometers in Tunnels. Presented at the 12th FIG Symposium on Deformation Measurements and Analysis the 3rd IAG Symposium on Geodesy for Geotechnical and Structural Engineering, Baden, 2006.

5 – FACULDADE DE CIÊNCIAS DA UNIVERSIDADE DE LISBOA

5.1 – PROJECTS

Project: **KARMA**

Title: Kinematics And Rheological Modelling of the Nubian-Eurasian plate boundary in the Azores

Principal Investigator: João Catalão

Principal Research Unit: Laboratório de Tectonofísica e Tectónica Experimental - LATTEX

Period of activity: 1/Jun/2005 to 31/12/2008

Goals: The main goal of KARMA is to derive a cinematic model for the Azores plate boundary and to design a comprehensive model for the Eurasia/Nubian plate boundary, valid at the "segment scale", able to incorporate the main conclusions of a series of detailed and complementary approaches supplied by other geophysical projects operating in this area. 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 will allow a reassessment of seismo-tectonics both in-land and offshore.

Project: **ESA - Project C1P 3149**

Title: Ground deformation of Azores islands based on INSAR, corner reflectors and GPS

Principal Investigator: João Catalão

Principal Research Unit: Laboratório de Tectonofísica e Tectónica Experimental - LATTEX

Period of activity: 1/Jun/2005 to 31/12/2008

Goals: The main objective of this project is to test the applicability of the corner reflectors to overcome short term decorrelation of SAR images pairs. To reach this objective we proposed to install in Faial island 6 corner reflectors.

DISPLAZOR, STAMINA and SARAÇORES projects, mentioned in the last report (1999-2002) have already ended in 2005.

5.2 – Papers published in International Journals (with referees)

Catalão, J., J.M. Miranda, N. Lourenço (2006), "Deformation associated with the Faial (Capelinhos) 1956 eruption. Inferences from 1937-1997 geodetic measurements". *Journal of Volcanology and Geothermal Research*, Vol 155, 3-4, 151-163. doi:10.1016/j.jvolgeores.2006.03.028.

Catalão, J., (2006) "Iberia-Azores Gravity Model (IAGRM) using multi-source gravity data". *Earth, Planets, Space*, 58, 277–286, 2006.

Catita, C., K.L.Feigl, J. Catalão, J.M.Miranda, L.M.Victor (2005) "Time series analysis of SAR data applied to the study of the co-seismic deformation of the 9th July 1998 Pico-Faial (Azores) earthquake" *International Journal of Remote Sensing*, Vol. 26, No 13, 10 July 2005, 2715-2729.

Catalão, J. and M.J. Sevilla (2004), "Inner and minimum constraint adjustment of marine gravity data". *Computers and Geosciences*, Vol. 30, Issues 9-10 pp. 949-957, DOI: 10.1016/j.cageo.2004.06.004

Navarro, A., J. Catalão, J.M. Miranda and R. M.S. Fernandes (2003) "Estimation of the Terceira island (Azores) main strain rates from GPS data". *Earth, Planets and Space*, Vol. 55 (10), pp. 637-642.

Antunes, C., R. Pail, J. Catalão (2003) "Geoid determination by point mass method". *Studia geophysica et geodetica*, Vol. 47, pp. 495-509.

Mendes, V.B. and E.C. Pavlis (2004). "High-accuracy zenith delay prediction at optical wavelengths". *Geophysical Research Letters*, Vol. 31, L14602, doi:10.1029/2004GL020308.

5.3 – Communications to International Meetings (with Publication of Extended Abstract or Publication of Communication on Acta Book)

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6 – CENTRO DE INVESTIGAÇÃO EM CIÊNCIAS GEO-ESPACIAIS E DEPARTAMENTO DE MATEMÁTICA APLICADA DA FACULDADE DE CIÊNCIAS DA UNIVERSIDADE DO PORTO

6.1 – MAIN AREAS OF ACTIVITY IN GEODESY

The activity at the Geo-Space Sciences Research Centre (CICGE) and Applied Mathematics Department, Faculty of Sciences, University of Porto, in the area of Geodesy and related fields, is organized around four main domains:

Satellite Positioning and Navigation
Satellite Altimetry
Remote Sensing and Image Processing
Geographical Information Systems

In the period covered by this report, 2003-2006, the activity was carried out, in all those domains and their applications, through research projects financed by national as well as international organizations. Some of the results from such activity are given in the annexed list of publications.

The two Masters Degree Courses, in Satellite Positioning and Navigation and in Remote Sensing, continue to be offered. The MSc Thesis produced during the same period are also included in the list.

Also in the list, are the PhD Thesis, already finished, whose research work was conducted under the supervision of elements of the Research Centre, within the area of geodesy and related fields.

Finally, it is also to be mentioned the organization of some International Meetings under the responsibility of members of the Centre.

6.2 – PUBLICATIONS

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7 – OBSERVATÓRIO ASTRONÓMICO PROF. MANUEL DE BARROS DA UNIVERSIDADE DO PORTO

7.1 – INTRODUCTION

Presently the main areas of research at the Astronomical Observatory of the University of Porto (OAUP) are essentially satellite positioning and navigation, with applications in geodynamics, coastal zones monitoring and mobile mapping, and airborne gravimetry.

The most relevant activities in the period 2003-2006 had been:

- Implementation of a Database and Analysis Center (GEODAC) in the scope of the activities of the Inter Commission Project of the International Association of Geodesy, WEGENER (in collaboration with the University of Delft and the University of Beira-Interior). In the scope of this project, systematic processing of an Iberian GPS network (including some GPS stations located in Northern Africa) is carried out.
- Implementation of algorithms for analysis of the spatial and temporal correlations in GPS time. These algorithms are being implemented successfully in the analysis of permanent networks in the scope of GEODAC.
- Implementation of algorithms for estimating trends (in GPS time series) with realistic error bars. A new method was developed which is an order of magnitude faster with no loss of accuracy in case there are no data gaps. When there are gaps in the data the new method still produces good results while retaining its gain in speed. Further improvement in the estimation of the trend in GPS data was done by removing the environmental effect of atmospheric loading.
- Development of the program CARGA. This program, developed in collaboration with other European institutions, allows the calculation of loading effects. It is being applied to the analysis of permanent GPS networks and also in international projects involving the study of tides using gravimetric observations.
Results of CARGA were compared with the values of the Special Bureau for Loading (SBL) which is part of the International Earth Rotation Service (IERS). Discrepancies were found not only between our results and theirs but also among the several sets of values available at the SBL. This led to a deeper investigation of the numerical accuracy of atmospheric loading computations.
- Maintenance of permanent GPS stations in the Azores region for geodynamic studies.
- Development of algorithms based on GPS/INS integration for airborne gravimetry.
- Reobservation of the absolute gravimetric station located in the grounds of the Astronomical Observatory (in collaboration with the Finnish Geodetic Institute).
- Monitorization of the coastal zone using space techniques for vulnerability and risk assessment.
- Implementation of a Mobile Mapping system based on the integration of GPS measurements with data from dead-reckoning sensors and video systems for acquisition of image.

The following list of publications and communications, resulting from the developed activities, expresses the main results achieved.

7.2 – COMMUNICATIONS AND PUBLICATIONS (2003-2006)

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

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FERNANDES, R.M.S., N. LOURENÇO, L. BASTOS, J.M. MIRANDA, B.A.C. AMBROSIUS, RON NOOMEN, AND WIM SPAKMAN (2004) – *Assessment of a dislocation model for the Azores plate boundary*. Presented at the 12th General Assembly of the WEGENER project, Tangier, Morocco, September, 2004.

R.M.S. FERNANDES, B.M.L. MEIJNINGER, L. BASTOS, B. A. C. AMBROSIUS, R. NOOMEN, ELISA BUFORN (2004) – *GPS constraints on the kinematics of the Iberian Peninsula and North Morocco*. Presented at the 12th General Assembly of the WEGENER project, Tangier, Morocco, September, 2004.

FERNANDES, R.M.S., L. BASTOS, J.M. MIRANDA, B.A.C. AMBROSIUS, R. NOOMEN, L. COMBRINCK E J. SUCURE (2004) – *Nubia and Somalia: the break-up of the African plate as derived from continuous GPS data*. Presented at the 4ª Assembleia Luso-Espanhola de Geodesia e Geofísica, Figueira da Foz, February 2004.

BAPTISTA, P., BASTOS, L, VELOSO-GOMES, F. (2004) - *Morfodinâmico de uma Obra de Protecção Costeira: O Quebra-mar da Aguda*. Presented at the 4ª Assembleia Luso-Espanhola de Geodesia e Geofísica, Figueira da Foz, February 2004.

BAPTISTA, P., BASTOS, L., FERNANDES, R.M.S., BERNARDES C., FERREIRA, O., DIAS, A. (2004). - *Monitoring Beach Erosion by DGPS – A Tool for Identify Coastal Hazards*. Presented at the Workshop RIMAR, January 2004.

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

FERNANDES, R.M.S., B.A.C. AMBROSIUS, L. BASTOS, J.M. MIRANDA, R. NOOMEN, W. SIMONS, W. SPAKMAN AND N. LOURENÇO (2004) – *Plate boundaries in the Azores region from GPS observations*. Presented at the VMSG Symposium, Delft, The Netherlands, Outubro, 2003 (winning poster).

BAPTISTA, P., BASTOS, L., JESUS, M. E., CORREIA E., (2003) - *Morphodynamic evolution of the sand-spit in the mouth of Douro river through DGPS monitorization*. Proceedings of 3 IAHR Symposium on River, Coastal and Estuarine Morphodynamics (RCEM 2003). Barcelona, Spain. pp. 1060-1067. September 2003.

CUNHA, S., BASTOS, L., TOMÉ, P., CUNHA, T. (2003) - *On the Integration of Inertial and GPS Data with an Odometer for Land Vehicles Navigation*. Proceedings of ION GPS 2003, Portland, USA, Setembro 2003.

FERNANDES, M. J., BASTOS, L., LEITE, F., TOMÉ, P. (2003) – *Gravity anomaly field from multisensor data*. Presented at the IUGG2003 Assembly, Sapporo, Japão, June, 30 to July, 11, 2003.

BAPTISTA, P., BASTOS, L., BERNARDES, C., DIAS, A., FERREIRA, O. (2003) – *Morphodynamic characterization of the foreshore using periodic DGPS observations: the Aveiro lagoon beach case*. Presented at the IUGG2003 Assembly, Sapporo, Japão, June, 30 to July, 11, 2003.

Invited talks

BASTOS, L., R. FERNANDES AND M. BOS (2006) – *Improvements in the determination of tectonic motions from GPS*. Presented at the International Geodetic Forum XiAn 2006”, ChangAn University, China, 10-16 October 2006.

SCHERNECK, H.-G., BOS, M. S. - *Ocean loading tides - a review*. Presented at the General Assembly of the European Geosciences Union, Vienna, Austria, April 2-7, 2006.

BASTOS, L. (2005) - *Técnicas espaciais na caracterização da dinâmica terrestre* . Invited talk in the Seminar “Forecasting and prevention in the mitigation of the effects of Natural Hazards”, IRICUP, University of Porto, January 2005.

BASTOS, L. (2003) - Exploring GPS/INS integration for airborne and terrestrial applications. Invited talk in “Ciclo de Conferências Internacionais” Institut of Geomatics, Barcelona, Spain, March 2003.