

# **PORTUGAL**

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

**INTERNATIONAL ASSOCIATION OF GEODESY  
IAG**

## **NATIONAL REPORT**

**1999 – 2002**

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

**HOLD AT SAPPORO, 30 JUNE – 11 JULY 2003**

**Coordinated by**

**Eng. João Manuel Agra 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 1999-2002.

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. Manuela Vasconcelos;
- *Instituto de Investigação Científica Tropical* (Tropical Science Research Institute) - report by Dr. José Nuno Lima;
- *Laboratório Nacional de Engenharia Civil* (National Laboratory of Civil Engineering) – report by Prof. João Casaca.
- *Faculdade de Ciências da Universidade de Lisboa* (Faculty of Sciences of the University of Lisboa) – report by Prof. Joaquim Pagarete;
- *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:

- Luisa Bastos (*Observatório Astronómico Prof. Manuel de Barros da Universidade do Porto*) as President of the WEGENER Sub-commission of Commission XIV - Crustal Deformation, under Section V – Geodynamics;
- João Agria Torres (*Instituto Geográfico Português and SPUIAGG*) as President of the EUREF Sub-commission for Europe of Commission X - Global and Regional Geodetic Networks, under Section I – Positioning.

## **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**

In 1999 the observation with GPS of the first order network in Portugal mainland was completed. During the period covered by this report the observation of the second order network of the mainland with GPS was started, being completed for about 40% of the trig points. The following standards are used to observe the 2<sup>nd</sup> order network:

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

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

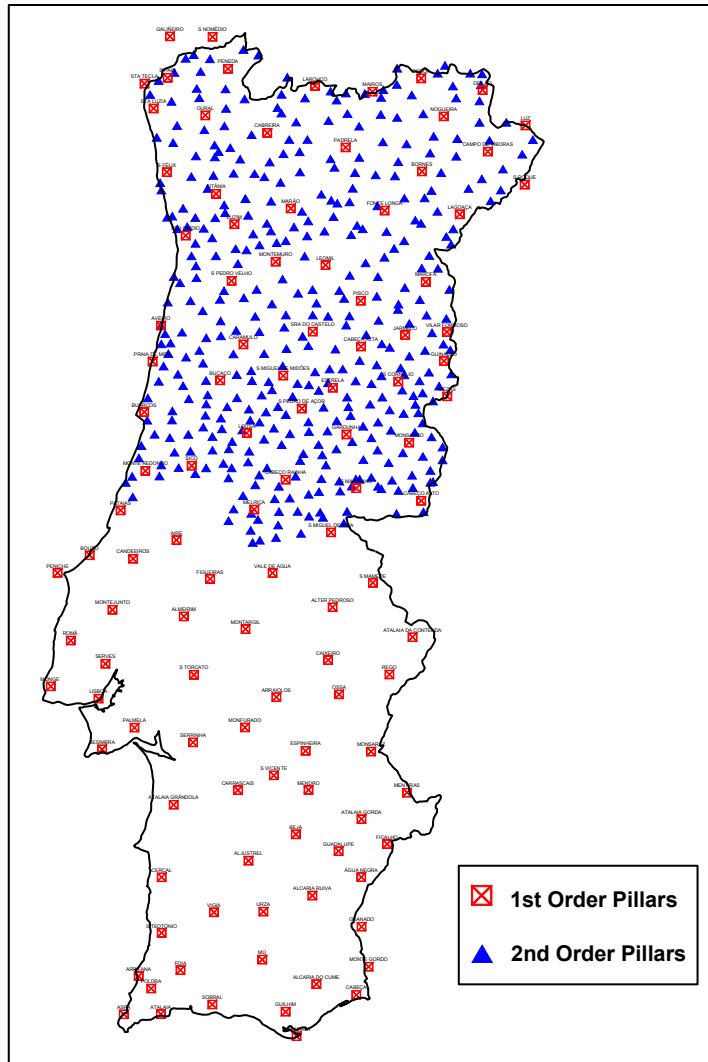


Figure 1 – Mainland Geodetic network observed with GPS until the end of 2002.

In the last years, IGP is carrying out the inspection and the material recovering of the classical geodetic network. This network comprises about 9000 trig points (mostly concrete pillars). The work in Madeira archipelago is already finished, the Azores archipelago is almost completed and in Portugal mainland about 80% of the network is recovered. The pillars that needed to be rebuilt were observed with GPS and recomputed.

### 2.2.2 High Precision Levelling Network

The work of observation of the high precision levelling lines has continued in the last years. In the period concerning this report, IGP accomplished about 350 km of levelling. In the year 2000, the whole network of the mainland was recalculated with the newest observations, based on the adjustment in geo-potential numbers. The conclusion of the densification of the gravimetric network was also important for this work, because it provided a more accurate model for the calculation of the geo-potential heights.

IGP is in charge of two tide gauges, in Cascais and Lagos, working, since 1882 and 1908, respectively. In a joint project between IGP and the Faculty of Science of the University of Lisbon (FCUL), the paper records from 1986 to 2000 of both tide gauges were digitised.

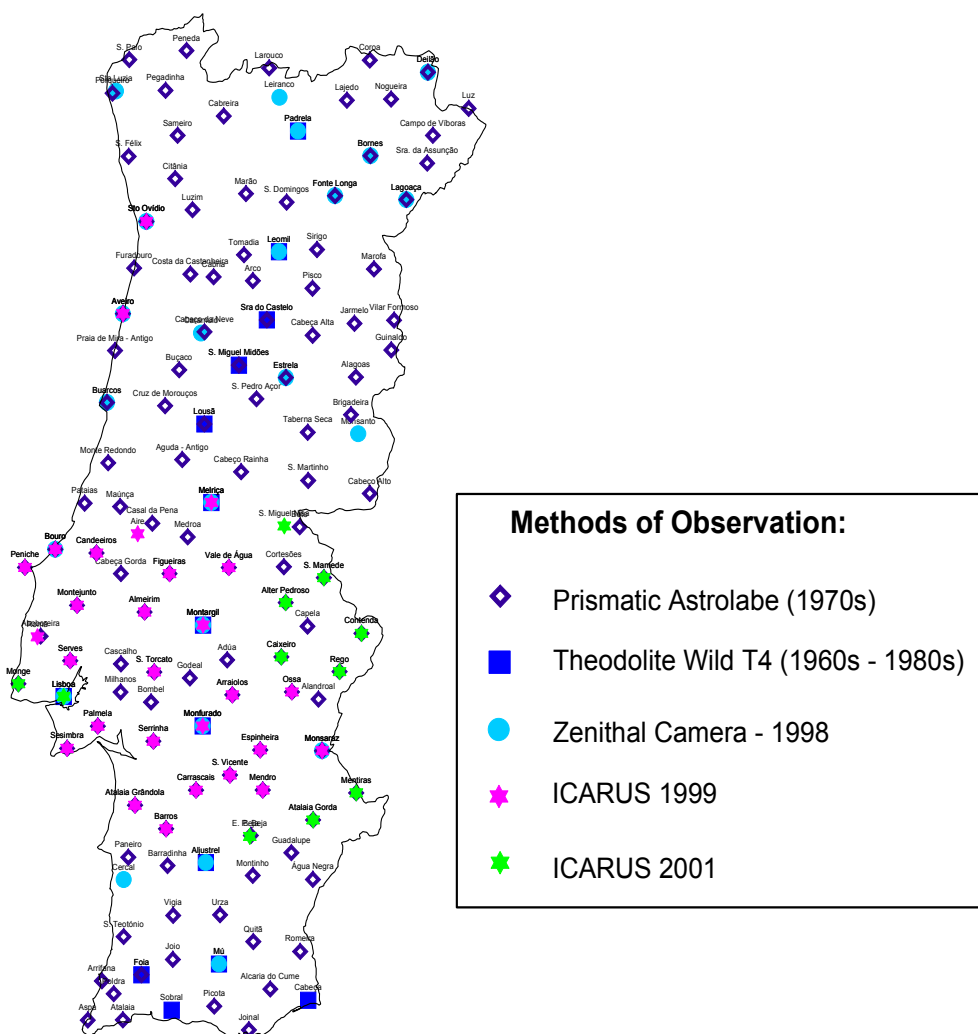
### 2.2.3 Vertical Deflection Points' Network

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 Zenith 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.

Figure 2 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 2 – Astronomical observations in Portugal Mainland.*

## 2.2.4 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 4 other stations: Beja and Mirandela in 2001, Melriça and Funchal (Madeira Archipelago) in 2002. The configuration of the present GPS permanent network is shown in figure 3.

All the data regarding these 8 stations can be obtained at the anonymous ftp of IGP: <ftp://ftp.igeo.pt/pub/gpsdata/>.



Figure 3 – GPS Permanent Network

## 2.3 – DETERMINATION OF THE GRAVITY FIELD

### 2.3.1 Gravimetric Network

As it was stated in the previous report, the densification of the gravimetric network in Portugal mainland, with an average distance of 5km, was finished in 1997. In the period covered by this report, 386 new gravimetric stations along the high precision levelling lines were observed. The present state of the gravimetric network is shown in figure 4.

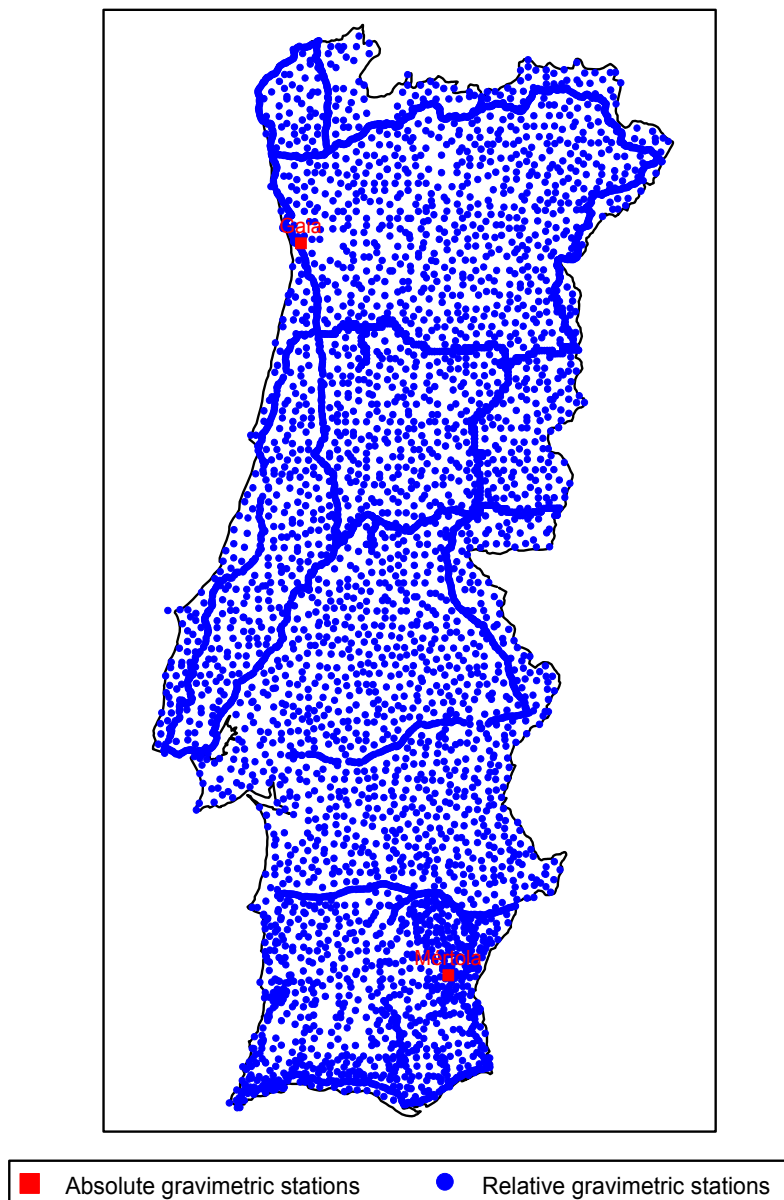


Figure 4 – Gravimetric network of Portugal mainland.

### 2.3.2 Geoid Model

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 3<sup>rd</sup> Hispano-Portuguese Assembly of Geodesy and Geophysics, held in Spain in 2002. The project of validation of this model should start this year, with the observation with GPS of about 100 benchmarks.

### 2.4 – OTHER ACTIVITIES

The EUREF 2002 Symposium was held in Ponta Delgada, Azores. IGP participated in the organisation of this event, in a co-operation with the Azorean authorities. The web site of EUREF presently is hosted by IGP.

In September 2002 a Geodetic Museum opened in the centre of Portugal, located near the point that is the origin of the local reference system of Portugal mainland. IGP is responsible for this museum.

## **2.5 – HUMAN AND MATERIAL RESOURCES**

The human resources of the Department of Geodesy of IGP are six surveying engineers and eight surveying technicians.

The equipment consist 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;
- gravimetric adjustment and computation software;
- triangulation adjustment and computation software;
- levelling adjustment and computation software;
- geodetic astronomy adjustment and computation software.

## **2.6 – PUBLICATIONS**

Catalão, J., **Vasconcelos, M., Kol, H.**, Sevilla, M. J., 2002 - *Geóide em Portugal – novos resultados*, paper presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Valencia, Spain.

Catalão, J., **Vasconcelos, M., Kol, H.**, Sevilla, M. J., 2002 - *Geóide em Portugal – novos resultados*, paper presented at the III Portuguese Conference of Cartography and Geodesy, Aveiro, Portugal.

**Crisóstomo, G., Medeiro, A., Pinto, J. T.**, 2002 – *Cálculo de Coordenadas ETRS89 por integração de observações clássicas com GPS*, paper presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Valencia, Spain.

**Crisóstomo, G., Silva, A., Medeiro, A., Pinto, J. T.**, 2002 – *Cálculo de Coordenadas ETRS89 por integração de observações clássicas com GPS*, poster presented at the III Portuguese Conference of Cartography and Geodesy, Aveiro, Portugal.

**Kol, H., Vasconcelos, M.**, 1999 - *Adensamento Gravimétrico em Portugal Continental: Estudos e Aplicações*, paper presented at the II Portuguese Conference of Cartography and Geodesy, Luso, Portugal.

**Kol, H., Vasconcelos, M.**, 2000 - *Adensamento Gravimétrico: Estudos e Aplicações*, paper presented at the 2<sup>nd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Lagos, Portugal.

**Kol, H., Taborda, R., Guerra, S.**, 2002 – *Recolha e Gestão de Dados Maregráficos do IGP*, poster presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Valencia, Spain.

**Kol, H., Taborda, R., Guerra, S.**, 2002 – *Recolha e Gestão de Dados Maregráficos do IGP*, poster presented at the III Portuguese Conference of Cartography and Geodesy, Aveiro, Portugal.

**Kol, H., Vasconcelos, M.**, 2002 - *Rede Portuguesa de Nivelamento Geométrico de Alta Precisão*, paper presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Valencia, Spain.

**Martins, C., Ribeiro, H.**, 2002 – *Observação da Rede Geodésica de 2<sup>a</sup> ordem com GPS*, paper presented at the III Portuguese Conference of Cartography and Geodesy, Aveiro, Portugal.

**Martins, C., Ribeiro, H.**, 2002 – *Observation of Second Order Portuguese Network with GPS*, poster presented at the EUREF 2002 Symposium, Ponta Delgada, Portugal.

**Martins, C., Ribeiro, H.**, 2002 – *Process and Adjustment of the Portuguese First Order Network*, poster presented at the EUREF 2002 Symposium, Ponta Delgada, Portugal.

**Martins, C., Ribeiro, H.**, 2002 – *Processamento e Ajustamento da Rede Portuguesa de 1<sup>a</sup> Ordem*, paper presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Valencia, Spain.

Mendes, V., **Pinto, J., Ribeiro, H.**, Pagarete, J., 1999 – *Determination by GPS of the displacements caused by the Fail seism of 9 July 1998*, poster presented at the XXII Assembly of IUGG, Birmingham, Great Britain.

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- Pereira, H., **Pinto, J. T., Kol, H., Ribeiro, H.**, 2002 – *TranscoordPro: um utilitário para a transformação de coordenadas*, paper presented at the VII Portuguese Encounter of Geographical Information Systems Users, Oeiras, Portugal.
- Pereira, H., **Pinto, J. T., Kol, H., Ribeiro, H.**, 2002 – *TranscoordPro: um utilitário para a transformação de coordenadas*, poster presented at the III Portuguese Conference of Cartography and Geodesy, Aveiro, Portugal.
- Pinto, J., Ribeiro, H.**, 2002 – *Aplicação da Resolução Directa de Triângulos Zenitais para Obtenção de Altitudes Ortométricas e Ondulações do Geóide, na Ilha do Faial*, paper presented at the III Portuguese Conference of Cartography and Geodesy, Aveiro, Portugal.
- Pinto, J. T.**, 1999 – *A ReNEP GPS*, paper presented at the XVII DIGSA Reunion, Lisbon, Portugal.
- Pinto, J. T., Ribeiro, H., Torres, J. A.**, 2000 – *A Rede de Estações Permanentes GPS do IPCC*, poster presented at the 2<sup>nd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Lagos, Portugal.
- Pinto, J. T.**, 2002 – *Duas Propostas para um Velho Problema*, paper presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Valencia, Spain.
- Pinto, J. T., Bürki, B., Ribeiro, H.**, 2000 – *ICARUS: Um Sistema Automático para Astronomia de Posição*, poster presented at the 2<sup>nd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Lagos, Portugal.
- Pinto, J.**, 1999 – *Infra-estruturas Geodésicas*, paper presented at the II Portuguese Conference of Cartography and Geodesy, Luso, Portugal.
- Pinto, J. T., Ribeiro, H., Martins, C., Alves, A., Geada, J.**, 2002 – *Recuperação e Reobservação da Rede Geodésica Nacional*, poster presented at the III Portuguese Conference of Cartography and Geodesy, Aveiro, Portugal.
- Pinto, J. T., Ribeiro, H., Martins, H., Guerreiro, J.**, 2002 – *Rede Nacional de Estações Permanentes GPS*, poster presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Valencia, Spain.
- Pinto, J. T.**, 2000 – *Resuming Zenithals*, poster presented at the EUREF 2000 Symposium, Tromsø, Norway.
- Pinto, J., Ribeiro, H.**, 1999 – *Using GPS Observations to Determine Vertical Refraction in Zenithal Observations*, poster presented at the XXII Assembly of IUGG, Birmingham, Great Britain.
- Pinto, J. T., Ribeiro, H.**, 2000 – *Usando GPS para Determinar Ângulos de Refracção e Desvios da Vertical*, paper presented at the 2<sup>nd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Lagos, Portugal.
- Ribeiro, H., Pinto, J. T.**, 1999 – *Estudo da Variação de Coordenadas da Estação Permanente de Cascais*, paper presented at the II Portuguese Conference of Cartography and Geodesy, Luso, Portugal.
- Ribeiro, H., Martins, C., Pinto, J. T.**, 2002 – *Observação da Rede Geodésica Nacional com GPS*, poster presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Valencia, Spain.
- Ribeiro, H., Pinto, J. T.**, 2002 – *Sistemas de Referência Europeus: ETRS89 e EVRS*, paper presented at the III Portuguese Conference of Cartography and Geodesy, Aveiro, Portugal.
- Ribeiro, H., Pinto, J. T.**, 2000 – *Using Cascais GPS Permanent Station for Geodynamic Purposes*, paper presented at the 10<sup>th</sup> General Assembly of the WEGENER Project, San Fernando, Spain.
- Ribeiro, H., Pinto, J. T.**, 2002 – *Using Cascais GPS Permanent Station for Geodynamic Purposes*, paper presented at the EUREF 2002 Symposium, Ponta Delgada, Portugal.
- Vasconcelos, M., Kol, H.**, 2002 - *Ajustamento da Rede de Nivelamento Geométrico de Alta Precisão de Portugal Continental*, poster presented at the III Portuguese Conference of Cartography and Geodesy, Aveiro, Portugal.
- Vasconcelos, M., Patrício, P.**, 2002 - *Co-ordinate Transformation in Portugal Mainland – a brief study*, poster presented at the EUREF 2002 Symposium, Ponta Delgada, Portugal.
- Vasconcelos, M., Patrício, P.**, 2002 - *Transformação de coordenadas em Portugal Continental – Estudo comparativo de vários métodos*, paper presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly on Geodesy and Geophysics, Valencia, Spain.
- Vasconcelos, M.**, 2002 - *Transformação de Coordenadas Rectangulares através de Funções Polinomiais*, paper presented at the Regional Encounter of Cartography and Geographical Information Systems, Madalena, Portugal.



### **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 Study of Volcanic Deformations in Fogo Island, Cape Verde**

Fogo Island, in the Cape Verde archipelago (North Atlantic), is a roughly conical volcanic edifice with 25 Km of base diameter and a summit that reaches an altitude of about 3000 m. Volcanic eruptions in the island are reported since the settlement in the 15<sup>th</sup> century, at average intervals of about 20 years. In the 20<sup>th</sup> century the activity subsided, with only two eruptions in 1951 and 1995. Fogo comprises 33000 inhabitants, of which 800 live inside the 9km-wide ancient collapse caldera, which is open towards the East.

This project objective is monitoring volcanic deformations in Fogo through (with) periodic GPS and microgravity surveys.

Between 1999 and 2001, four GPS and three microgravity surveys were made, with a repeat period of about 6 months. A network composed of 23 geodetic monuments, with stable reinforced concrete foundations, was previously implemented for this purpose, covering the entire island with basis lengths between 2 and 8 Km.

For the GPS surveys, seven GPS Trimble 4000 SSE receivers were used, and the observations were processed with Bernese 4.2 software. During the data processing the IGS permanent stations and precise orbits were used. Two LaCoste & Romberg G gravimeters were used together with the GPS observations for three of the four campaigns. The Gravimetry data were processed with a Gravimetry software pack developed in Finnish Geodetic Institute.

##### **3.2.2 Geodetic Network of Mozambique**

This project has three main objectives. The first objective is to update the classical geodetic triangulation of Mozambique with GPS and to recover a small triangle chain between the basis of Zimuala and Buzi. The second objective 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 (now Centro de Geodesia of IICT).

Activities:

- Observation of the triangle chain between the basis of Zimuala and Buzi with GPS (November 2000);
- Processing those GPS observation with Bernese GPS Software 4.2;
- Integration of the GPS results in Mozambique Geodetic Network;
- Digitalisation of geodetic data field books to build a digital database.

##### **3.2.3 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 (now Centro de Geodesia of IICT).

Activities:

- Inclusion of Hydrographical Missions geodetic triangle chains in the Geodetic Network of Angola;
- Conclusion of the trigonometric levelling;
- Development of specific software.

### **3.2.4 The Geodesy of Guinea-Bissau, Cape Verde and S. Tome and Prince**

This project is concerned with the development of research studies using all geodetic data from the previous geographic and hydrographical missions of Guinea-Bissau, Cape Verde and S. Tome and Prince.

Activities:

- Computation and adjustment of Fogo and Brava island geodetic triangulation network;
- Computation and adjustment of Fogo and Brava island trigonometric levelling networks;
- Processing with Bernese GPS Software the first GPS campaign in Cape Verde Archipelago (this campaign was carried out by the Portuguese Institute for Cartography and Cadastre (IPCC) and Cape Verde's National Agency for Cartography and Cadastre (SNCCCV) in April and May of 1999, and it consists of 18 GPS sessions, observed with 2 Trimble 4800 and 2 Trimble 4000 SSE GPS receivers, allowed to occupy 31 stations of the geodetic network in 9 islands of the archipelago);
- Computation of the parameter transformation between the local data of Cape Verde islands and the ITRF97 (Bursa-Wolf, Molodensky and Ten-parameter Affine Transformation).

### **3.2.5 Geodetic Networks of East Timor**

The objective of this project is the development of research studies with all geodetic data from the ex-Missão Geográfica de Timor (now Centro de Geodesia of IICT).

Activities:

- Computation and adjustment of Timor geodetic triangulation network;
- Computation and adjustment of Timor trigonometric levelling network.

## **3.3 – HUMAN AND MATERIAL RESOURCES**

The human resources are one University Professor, one Head-Chief Geodesist, one Researcher (PhD equivalent) and one Research Assistant.

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., Lima, J.N., Heleno, S.I.N., Lazaro, C., d'Oreye, N., Ferreira, A.M., Barros, I., Santos, P., Bandomo, Z., Day, S.J., Osório, J.P., Baio, M., Matos, J.L.** - "Multiparameter Monitoring of Fogo Island, Cape Verde, for Volcanic Hazard Mitigation".(Submitted to Journal of Volcanology and Geothermal Research).
- Lima, Nuno** – "O Fim dos Sistemas Geodésicos Locais ou o Aperfeiçoamento dos Modelos de Transformação Entre estes Sistemas Geodésicos Globais?", Actas da II Conferência Nacional de Cartografia e Geodesia, Setembro de 1999, Instituto Português de Cartografia e Cadastro, Junho de 2000, pp. 34-40.
- Lima, J. Nuno** – "O Sistema Global de Posicionamento na monitorização geodésica da Ilha do Fogo", Tese de Dissertação para o concurso de acesso à categoria de Investigador Auxiliar, Instituto de Investigação Científica Tropical, Lisboa, Dezembro de 2000.
- Lima, Nuno, Osório, J., Lázaro, C., Santos, P., Heleno, S., Matos, J., Fonseca, J.** – "Rede GPS para o Controlo Geodésico do Vulcão da Ilha do Fogo, Cabo Verde", Actas da II Conferência Nacional de Cartografia e Geodesia, Setembro de 1999, Instituto Português de Cartografia e Cadastro, Junho de 2000, pp. 113-119.
- Lima, Nuno, Torres, J. A., Cruz, G.** – "Estabelecimento do Referencial Geodésico de cabo Verde com GPS – resultados preliminares", Actas da II Assembleia Luso Espanhola de Geodesia e Geofísica, Lagos, 8 a 12 de Fevereiro de 2000.
- Lima, J.N., Heleno, S.I.N., Fonseca, J.F.B.D.,** - "Establishment of a GPS control network in FogoVolcano, Cape Verde". (Submitted to Proceedings of III Assembleia Luso-Espanhola de Geodesia e Geofísica, Valencia, Spain, 2002).
- Lima, J.N., Lazaro, C., Santos, P., Heleno, S.I.N., Fonseca, J.F.B.D.,** - "GPS and microgravimetry for Fogo Island volcano control". (Submitted to Proceedings of III Assembleia Luso-Espanhola de Geodesia e Geofísica, Valencia, Spain, 2002).
- Lima, J. Nuno, Torres, J. Agria, Kol, M. Helena** – "Geo-responsabilização: O que podemos esperar da nossa infra-estrutura geodésica e em que condições a podemos utilizar?" (Submitted to Proceedings of III Conferência Nacional de Cartografia e Geodesia, Aveiro, Portugal, 2002).

## 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 with the aim to support the improvement and updating of the important contribution provided in a regular basis by the Applied Geodesy Centre (Núcleo de Geodesia Aplicada – NGA) to the observations of big 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 big engineering works observation, essentially at two levels:

- i) equipments for geodetic observation;
- ii) methods and models for the treatment of the observed data and quality evaluation of the results.

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

**Henriques, M. J., Casaca, J.** – “O Controlo da Qualidade em Redes Locais para a Observação de Grandes Barragens”. Presented at the II Conferência Nacional de Cartografia e Geodesia, Luso. Portugal, 1999.

**Casaca, J.** – “A Correção Instrumental e Ambiental dos Distanciómetros Electromagnéticos”. Estudo para o PIP do LNEC. Série ICT, ITB20.

**Casaca, J.** – “O Método da Variação de Coordenadas na Observação Geodésica de Barragens”. Estudo para o PIP. Série ICT, ITB21.

**Henriques, M. J., Casaca, J.** – “Monitoring Vertical Displacements by Means of Geometric Levelling”. Presented at the III Seminário Internacional “*Historical Constructions 2001*”, Guimarães, 2001.

**Henriques, M. J., Casaca, J.** – “The Geodetic Surveying Methods in the Monitoring of Large dams in Portugal”. Presented at the XXII FIG Congress, Washington D.C., 2002.

**Henriques, M. J.** – “Estratégia para a Calibragem dos Distanciómetros Electromagnéticos usados na Observação Geodésica de Barragens”. Estudo para o PIP do LNEC. Série ICT, ITB26.

**Casaca, J., Baio, M., Falcão, A. P.** – “Avaliação do Desempenho Operacional da Transformação de Molodensky”. Presented at the III Conferência Nacional de Cartografia e Geodesia, Aveiro, Portugal, 2002.

**Henriques, M. J., Coelho, J., Leal, J.** – “Observação Geodésica do Pavilhão Atlântico: Um Exemplo de Apoio à Decisão”. Presented at the III Conferência Nacional de Cartografia e Geodesia, Aveiro, Portugal, 2002.

## 5 – FACULDADE DE CIÊNCIAS DA UNIVERSIDADE DE LISBOA

### 5.1 – PROJECTS (1999-2002)

Project: **DISPLAZOR**

Title: Tectonic, volcanic and landslide displacement monitoring at Faial, Pico and S. Jorge (Azores) using GPS - DISPLAZOR

Principal Investigator: Virgílio de Brito Mendes

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

Period of activity: 1/1/2001 to 31/1/2003

Goals:

**Neotectonics:**

- 1) to monitor and quantify seismic and aseismic surface displacements on the active faults of Faial, Pico, and S. Jorge;
  - 2) to analyse the discrepancies between published velocities predicted by global plate tectonic models for the Azores region (RM2, NUVEL-1, etc.) and slip rates estimated for the studied active faults on the islands;
  - 3) to quantify how much of the neotectonic deformation is caused by co-seismic, post-seismic, or aseismic slip;
  - 4) to verify if currently used correlations between surface displacement, rupture length, rupture area, and magnitude of the seismic events are directly applicable to the Azores region;
  - 5) to confirm and quantify the occurrence of decoupling of the general oblique tectonic displacement in time and space;
  - 6) to monitor the geodynamics of the submarine region between the three islands, where important active faults exist.
- Volcanism: To monitor and quantify ground inflation/deflation linked to magmatic movements in the active volcanic systems.
- Mass movements: To monitor and quantify slope instability

Project: **GEOALGAR**

Title: **Geodynamical Monitoring and Seismic Characterization of the Algarve Region - GEOALGAR**

Principal Investigator: Joaquim Pagarete

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

Period of activity: 1/5/2000 to 31/1/2002

Goals:

**Seismicity:**

- 1) Full evaluation of the seismic hazard based on the data already collected, which requires a rigorous hypocenter computation in this region requires, using simultaneous inversion of the velocity model and hypocenter parameters.
- 2) Computation of focal mechanisms, based on P-wave polarities and S-wave polarisations measured using a technique of thorough search in the fault plane parameters space with a probabilistic approach.
- 3) Estimation of the stress field direction, based on shear-wave splitting analysis, and seismic anisotropy studies in the upper crust.

**Neotectonics:**

- 4) Quaternary activity in this region is demonstrated by vertical crustal movements and by active structures comprising several active faults. However, these structures are poorly understood and it is important to monitor the displacements between those structures using geodetic means.

**Actual Geodynamics:**

- 5) In order to accomplish that study, three epochs of Global Positioning System (GPS) observations have been carried out in the Algarve region (two under this project).
- 6) The GPS-derived velocity field obtained from these repeated campaigns will now be estimated, which together with the outcome of the seismic data analysis will surely contribute significantly for the understanding of the geodynamic behavior and of the seismic hazard of the entire Algarve region.

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Project: **SHELT** (PRAXIS/P/CTE/11178/1998 - POCTI/CTE/11178/1998)

Title: Seismic Hazard Evaluation of the Lower Tagus Valley

Principal Investigator: João Manuel Lopes Cardoso Cabral

Principal Research Unit: LATTEX

Granting Institution: Fundação para a Ciência e a Tecnologia

Budget: € 119712

Period of activity: 1999/12/15 - 2002/08/31 (requested protract to 2003/12/31)

Goals:

To develop multidisciplinary studies in order to achieve the necessary information to estimate the Lower Tagus Valley Seismic Hazard, namely:

- (a) improve the knowledge of the neotectonic activity and in particular the regional seismogenic tectonic structures (seismic source characterization),
- (b) improve the knowledge of the regional seismicity,
- (c) improve the knowledge of the lithological composition and 3D geometry of the sedimentary filling of the Lower Tagus Basin,
- (d) perform the geophysical characterization of existing geological bodies (seismic propagation media), including i) a geotechnical characterization and ii) a seismic modelling.

At the items c) and d) it is expected to improve the estimation of the physical parameters needed for the evaluation of superficial seismic movements and consequently the seismic effects on a certain site.

In this last project the geodetic team of FCUL is also participating, as it is participating on two other projects (STAMINA and SARAÇORES), whose principal investigators belong to the area of Geophysics.

## **5.1 – PUBLICATIONS (1999-2002)**

### **Papers published in International Journals (with referees)**

**Mendes, V.B.** and R.B. Langley (1999). "Tropospheric zenith delay prediction accuracy for high-precision GPS positioning and navigation." *Navigation*, Vol. 46, No. 1, pp. 25-34

**Mendes, V.B.** and R.B. Langley (2000). "An analysis of high-accuracy tropospheric delay mapping functions." *Physics and Chemistry of the Earth, Part A*, Vol. 25, No. 12, pp. 809-812.

Niell, A. E., A. J. Coster, F. S. Solheim, **V. B. Mendes**, P. C. Toor, R. B. Langley, C. A. Upham (2001). "Comparison of measurements of atmospheric wet delay by radiosonde, water vapor radiometer, GPS, and VLBI." *Journal of Atmospheric and Oceanic Technology*, Vol. 18, No. 6, pp 830-850.

**Mendes, V.B.**, G. Prates, E.C. Pavlis, D.E. Pavlis, and R.B. Langley (2002). "Improved mapping functions for atmospheric refraction correction in SLR". *Geophysical Research Letters*, Vol. 29, No. 10, 1414, doi:10.1029/2001GL014394.

Carrilho F., P. Teves-Costa, I. Morais, **J. Pagarete** and R. Dias (2002). GEOALGAR project – First results on Seismicity and Fault-Plane Solutions. *PAGEOPH* (in press).

**Catalão, J., C. Catita**, J.M. Miranda e J.A. Dias (2002) "Photogrammetric analysis of the coastal erosion in Algarve (Portugal)." *Géomorphologie*, nº 2, pp. 119-126

Fernandes, M.J., L. Bastos and **J. Catalão** (2000). "The role of dense ERS altimetry in the determination of the marine geoid in Azores." *Marine Geodesy*, Vol. 23, N. 1, pp. 1-16.

**Catalão, J.** and M.J. Sevilla, (1999) "Comparison between EGM96 and FCUL96B tailored geopotential model for the north-east Atlantic." *Bollettino di Geofisica ed Teorica applicata*, Vol. 40, n.3-4, pp. 255-260.

Arabelos, D., S.D. Spatalas, I.N. Tziavos, M.J. Sevilla, G. Rodriguez, C. de Toro, **J. Catalão** and **J. Calvão** (1999) "A new high resolution geoid for the north-east Atlantic." *Bollettino di Geofisica ed Teorica applicata*, Vol. 40, n. 3-4, pp. 411-420.

**Catalão, J.** and M.J. Sevilla (1999). "The effect of high precision bathymetric model on geoid computation." *IGS Bulletin*, N. 10, pp 91-99.

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

- Prates, G, **V.B. Mendes**, L. Santos, and R. B. Langley (2000). "Temperatura média da atmosfera: estudo da exactidão de modelos." *Actas da 2ª Assembleia Luso-Espanhola de Geodesia e Geofísica*, Lagos, Portugal, 8-12 February 2000, pp. 45-46 (Abstract in English).
- Mendes, V.B.**, G. Prates, L. Santos, and R.B. Langley (2000). "An evaluation of models for the determination of the weighted mean temperature of the atmosphere." *Proceedings of The Institute of Navigation 2000 National Technical Meeting*, Anaheim, CA, U.S.A., 26-28 January 2000, pp. 433-438.
- Mendes, V.B.** and E.C. Pavlis (2002). "Atmospheric refraction at optical wavelengths: problems and solutions." Presented at the 13<sup>th</sup> International Laser Ranging Workshop, Washington D.C., October 07 - 11, 2002 ([http://cddisa.gsfc.nasa.gov/lw13/docs/papers/atmos\\_mendes\\_1m.pdf](http://cddisa.gsfc.nasa.gov/lw13/docs/papers/atmos_mendes_1m.pdf)).

**Communications to National Meetings (With Publication of Extended Abstract or Publication of Communication on Acta Book)**

- Pagarete J. e V.B. Mendes** (2000) "Reflexão sobre o uso de redes geodésicas para controlo geodinâmico e o estabelecimento de um novo «datum» geodésico." *Actas da II Conferência Nacional de Cartografia e Geodesia*, 23-24 Setembro 1999, Luso, Ed. Instituto Português de Cartografia e Cadastro, Lisboa, pp. 17-27.
- Santos, L., G. Prates e **V.B. Mendes** (2000). "Relação entre o atraso troposférico húmido e o vapor de água precipitável: comparação de modelos." *Actas da II Conferência Nacional de Cartografia e Geodesia*, 23-24 Setembro 1999, Luso, Ed. Instituto Português de Cartografia e Cadastro, Lisboa, pp. 41-48.

**Communications to National and International Meetings (Without Publication of Extended Abstract or Publication of Communication on Acta Book)**

- Mendes, V.B.**, J. Pinto, H. Ribeiro, and **J. Pagarete** (1999). "Determination by GPS of the displacements caused by the Faial Seism of 9 July 1998." Presented at the IUGG XXII General Assembly, 19-30 July, Birmingham, UK. (Abstract: Book of Abstracts, p. B.79).
- Elósegui, P., D. Ben Sari, J.M. Dávila, J.L. Gárate, **V.B. Mendes**, D. Ouzar, **J. Pagarete**, R. Reilinger, A. Rius, J.Talaya, R. Bennett, and J.L. Davis (1999). "The AMIGO Project: Present-day crustal deformation of the Western section of the Africa-Eurasia Plate Boundary Zone.", Presented at the IUGG XXII General Assembly, 19-30 July, Birmingham, UK. (Abstract: Book of Abstracts, p. B80).
- Pagarete, J. e V.B. Mendes** (1999). "Redes geodésicas para controlo geodinâmico em Portugal Continental e Insular." Apresentada na II Conferência de Cartografia e Geodesia, 23-24 de Setembro, Luso.
- Elósegui, P., D. Ben Sari, J.M. Dávila, J. Gárate, **V.B. Mendes**, D. Ouzar, **J. Pagarete**, R. Reilinger, A. Rius, J.Talaya, R. Bennett, and J.L. Davis (1999). "AMIGO GPS measurements to investigate geodynamic processes along the western section of the Africa-Eurasia plate boundary zone." Presented at the AGU Fall Meeting, 6-10 December, S. Francisco, CA. (Abstract: *EOS, Transactions of the American Geophysical Union*, Vol. 80, No. 46, p. F1066).
- Dávila, J.M., D. Ben Sari, P. Elósegui, J. Gárate, **V.B. Mendes**, D. Ouzar, **J. Pagarete**, R. Reilinger, A. Rius, J. Talaya, R. Bennett, and J.L. Davis (2000). "El proyecto AMIGO: Estudios GPS multidisciplinares en la región occidental de la frontera de placas Euroasiática y Africana. Situación actual." Apresentada na 2ª Assembleia Luso-Espanhola de Geodesia e Geofísica, realizada em Lagos, 8-12 de Fevereiro de 2000 (Livro de Resumos: p. 23).
- Bennett, R., D. Ben Sari, J. Davis, P. Elósegui, J. Garate, J. Martin Davila, **V. Mendes**, D. Ouzar, **J. Pagarete**, R. Reilinger, A. Rius (2000). "The AMIGO Project: Present-day crustal deformation of the western section of the Alpine-Mediterranean plate boundary zone." Presented at The Tenth General Assembly of the WEGENER Project (WEGENER 2000), San Fernando, Spain, September 18-20. (Abstract: Boletín ROA No. 3/2000, Real Instituto y Observatorio de la Armada, San Fernando, Spain).

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- Elósegui, P., R. Bennett, D. Ben Sari, J. M. Dávila, J. Gárate, **V. Mendes**, D. Ouzar, **J. Pagarete**, R. Reilinger, A. Rius, J. Talaya, and J. L. Davis (2000). "Present-day pattern of crustal deformation along the western section of the Africa-Eurasia plate boundary zone from AMIGO GPS measurements." Presented at the European Geophysical Society XXV General Assembly, 20-24 April, Nice, France (Abstract: *EGS Abstracts*).
- Pavlis, E. and **V. B. Mendes** (2000) "Improved mapping functions for atmospheric refraction corrections for laser ranging: preliminary validation results." Presented at the 12th International Workshop on Laser Ranging, 13-17 November, Matera, Italy.
- Elósegui, P., J. M. Dávila, R. Bennett, D. Ben Sari, J. L. Davis, J. Gárate, **V. Mendes**, D. Ouzar, **J. Pagarete**, R. Pysklywec, R. Reilinger, A. Rius, J. Talaya (2001). "Global Positioning System constraints on active tectonics in the Alboran Sea region." Presented at the European Geophysical Society XXVI General Assembly, 25-30 March, Nice, France (Abstract: *EGS Abstracts*).
- Pavlis, E. C. and **V. B. Mendes** (2001) "Validation of improved mapping functions for atmospheric corrections in laser ranging." Presented at the European Geophysical Society XXVI General Assembly, 25-30 March, Nice, France (Abstract: *EGS Abstracts*).
- Dávila, J. M., D. Ben Sari, P. Elósegui, J. Gárate, **V. B. Mendes**, D. Ouzar, **J. Pagarete**, R. Reilinger, A. Rius, J. Talaya, R. Bennett and J. L. Davis (2001). "AMIGO Project: An international GPS effort for studying the Western Section of the Eurasia-Africa plate boundary." Presented at Workshop on the Geodynamics of the Western Part of Eurasia-Africa Plate Boundary (Azores-Tunisia), San Fernando, Spain, May 31 – June 2. (Abstract: Boletín ROA No. 3/2001, Real Instituto y Observatorio de la Armada, San Fernando, Spain).
- Pagarete, J.**, F. Carrilho, I. Morais, P. Teves-Costa, R. Dias, M.L. Senos, **V.B. Mendes**, L. Matias and G. Manuppella (2001). "Geodynamic Monitoring and Seismic Characterization of the Algarve Region - GEOALGAR Project." Presented at Workshop on the Geodynamics of the Western Part of Eurasia-Africa Plate Boundary (Azores-Tunisia), San Fernando, Spain, May 31 – June 2. (Abstract: Boletín ROA No. 3/2001, Real Instituto y Observatorio de la Armada, San Fernando, Spain).
- Mendes, V.B.** and R.B. Langley (2002). "Revised radio refractive index formulae and their effect on GPS zenith delay prediction and estimation." Presented at *Position Location and Navigation Symposium 2002 (PLANS2002)*, Palm Springs, CA, April 15-18.
- Navarro, A., J. Catalão** and J.M. Miranda (2002) "A contribution for the understanding of the deformation pattern across the Terceira Axis". Presented at the *XXVII General Assembly of the EGS, Session G5*; 21-26 April, Nice, France.
- Catita, C., J. Catalão**, J.M. Miranda and L.M. Victor (2002) "The July 9, 1998 Pico-Faial, Azores, Earthquake: Co-seismic Deformation detected by radar interferometry". Presented at the *XXVII General Assembly of the EGS, Session G5*; 21-26 April, Nice, France.
- Catalão, J.**, Vasconcelos, M., H. Kol, M.J. Sevilla (2002) "Portuguese Geoid – new results". Presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly of Geodesy and Geophysics, 4-8 February, Valencia, Spain, p. 72.
- Navarro, A., J. Catalão** and J.M. Miranda (2002) "Uma contribuição para o conhecimento do padrão de deformação na ilha Terceira" Presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly of Geodesy and Geophysics, 4-8 February, Valencia, Spain, p.82.
- Catita, C., J. Catalão**, J.M. Miranda and L.M. Victor (2002) " Sismo de 9 de Julho, do Faial, Açores: Deformação co-sísmica observada a partir de interferometria SAR" Presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly of Geodesy and Geophysics, 4-8 February, Valencia, Spain, p. 83.
- Viegas, G.M., J.M. Miranda and **J. Catalão** (2002) "Earthquake-ruptured fault parameters determination from surface displacements using simulated annealing as an inversion technique: application to the Mw = 6.1 9<sup>th</sup> July 1998 Faial earthquake". Presented at the 3<sup>rd</sup> Hispano-Portuguese Assembly of Geodesy and Geophysics, 4-8 February, Valencia, Spain, p. 133.
- Catalão, J.** and M.J. Sevilla (2001) "Merging satellite derived gravity anomalies with ship gravity data in the frequency domain". Presented at the IAG2001 Scientific Assembly, 2-7 September, Budapest, Hungary.



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- Catalão, J., C. Catita**, J.M. Miranda and R.M.S. Fernandes (2001) "Numerical Modelling of the Coseismic Deformation of 1998 Faial Earthquake with Geodetic data". Presented at the IAG2001 Scientific Assembly, 2-7 September, Budapest, Hungary.
- Catalão, J., C. Catita**, J.M. Miranda e J.A. Dias (2000) "Analyse photogrammétrique de l'érosion côtière du Algarve (Portugal)". Apresentação no Geomorphology and Natural Hazards, International Workshop, Lille, October 19-21, 2000.
- Catalão, J., C. Catita**, J.M. Miranda e J.A. Dias (2000) "Photogrammetric analysis of the coastal erosion in Algarve (Portugal)." Apresentação no Meeting "GPS and SAR Interferometry on volcanoes", Catania, Italy 13-14 June of 2000.
- Catalão, J.** and M.J. Sevilla (2000) "Satellite derived gravity anomalies applied to gravity field". Apresentado na *XXV General Assembly of the EGS, Session G7: Techniques for Local Geoid Determination*; 25-29 April, Nice, France.
- Antunes, C.** and **J. Catalão** (2000) "On the comparison between point mass and collocation methods for geode determination" Apresentado na *XXV General Assembly of the EGS, Session G7: Techniques for Local Geoid Determination*; 25-29 April, Nice, France.
- Antunes, C., R. Pail e **J. Catalão** (2000) "Determinação do campo tendência na aplicação da colocação para a determinação local do geóide." Comunicação apresentada na 2ª Assembleia Luso-Espanhola de Geodesia e Geofísica. Lagos 8-12 de Fevereiro de 2000.
- Catalão, J., C. Catita**, J.M. Miranda e J.A. Dias (2000) "Aplicação de técnicas fotogramétricas na medição da taxa de recuo da arriba no Algarve (Olhos de Água –Quarteira)." Apresentado na 2ª Assembleia Luso-Espanhola de Geodesia e Geofísica. Lagos, 8-12 de Fevereiro de 2000.
- Catalão, J.** e M.J. Sevilla (2000) "Estudo do efeito de um modelo de batimetria de elevada precisão no cálculo da ondulação do geóide no arquipélago dos Açores", Apresentada na 2ª Assembleia Luso-Espanhola de Geodesia e Geofísica. Lagos 8-12 de Fevereiro de 2000.
- Catalão, J.** and M.J. Sevilla (1999) "The effect of high precision bathymetric model on geoid computation." Apresentado na IUGG – General Assembly of the International Union of Geodesy and Geophysics. Birmingham 15-30 July 1999.
- Catalão, J.** e M.J. Sevilla (1999) "A inversão de dados altimétricos no contexto da modelação do campo gravítico." Apresentada na II Conferência Nacional de Cartografia e Geodesia – Infraestruturas Cartográficas e Geodésicas para a próxima geração- Grande Hotel do Luso, 23 e 24 de Setembro de 1999.
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- C. Antunes** e **J. Catalão** (1999) "Diferentes métodos e soluções do geóide." Comunicação apresentada na II Conferência Nacional de Cartografia e Geodesia – Infraestruturas Cartográficas e Geodésicas para a próxima geração- Grande Hotel do Luso, 23 e 24 de Setembro de 1999.

## 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

This is a joint report of the geodetic activities carried out in the Geo-Space Sciences Research Center and the Department of Applied Mathematics of the Faculty of Sciences of the University of Porto. The main areas of activity are:

Aerial and Satellite Altimetry  
Satellite Positioning and Navigation  
Space Geodesy and Geodynamics

### 6.2 – HUMAN AND MATERIAL RESOURCES

#### Research Team

Ph. D's	4
Assistants	1
Post-Graduate Students	14

It must be pointed that, during the year 2002, the Center and the Department have received, for permanence of some months, post-graduated students and post-docs from other countries.

#### Main Equipment

- Two Single frequency GPS+GLONASS receivers (Ashtech GG24)
- Dual frequency GPS receiver (Trimble 4000 SSE) and access to other five of the same kind
- Geoexplorer 2 and Geoexplorer 3 Trimble GPS receivers
- Trimble ProXR GPS receiver
- Sokkia Radian RTK GPS system
- LaCoste & Romberg gravimeters
- Total stations
- Theodolites and geodetic levels
- Plotter
- Digital table
- Laptop computers
- Personal computers, printers, plotters, scanners
- Specialised geodetic software for different applications (data processing, analysis, adjustments, computations)
- Precise control geodetic network

Besides that, it should be mentioned all the facilities existing at the new Building of the Department of Applied Mathematics, where the research team is now located, from the beginning of 2002.

### 6.3 – PROJECTS WITH EXTERNAL FUNDING

*Geodetic Methods for the Study of the Seismotectonics of Southern Portugal and Azores-Gibraltar Region (1996)*

*Satellite Space Navigation Technology, Sub-Project C of the Project Dynamics and Control of Flexible Space Structures with Application to SAR Remote Sensing Satellites (1997)*

*Natural Hazards Associated with Sea Level (1997)*

*Study of Deformations of Volcanic Origin, in Fogo Island, Cape Verde, with GPS (1999)*

*The Space Technology and the Automatic Computing in the Teaching-Learning Procedure (2001)*

*Requirements for GALILEO from the Precise Geodetic-Point-of-View (2001)*

#### 6.4 – EDUCATION

Geodesy is one of the more important areas in the curriculum for the Degree-Course in *Surveying Engineering* at the Faculty of Sciences of the University of Porto.

In the academic year 2000-2001, it was organized, at the Department, a new Master's Degree Course in *Satellite Positioning and Navigation*.

The Project *The Space Technology and the Automatic Computing in the Teaching-Learning Procedure* was proposed, in connection with an High School, in order to involve young students in satellite positioning techniques.

#### 6.5 – OBSERVATIONAL GEODETIC CAMPAIGNS

During the period covered by the present Report, several GPS and Gravity Campaigns were organized.

#### 6.6 – PUBLICATIONS AND COMMUNICATIONS

- BASTOS, L., P. TOMÉ, T. CUNHA, M. J. FERNANDES and S. CUNHA (2002) – “*Gravity anomalies from airborne measurements - experiments using a low cost IMU device*”, International Association of Geodesy Symposia, Vol. 123, 253-258, Sideris M. G. (ed.), Springer Verlag.
- FERNANDES M. J., L. BASTOS and M. ANTUNES (2002) – “*Coastal Satellite Altimetry – Methods for Data Recovery and Validation*”, Proceedings of the 3<sup>rd</sup> Meeting of the International Gravity & Geoid Commission (GG2000), Thessaloniki, Greece, August 26-30, 2002.
- FERNANDES, M. J. and M. ANTUNES (2002) – “*Eight Years of Satellite Radar Altimetry in The Northeast Atlantic*”, Actas da 3<sup>a</sup> Assembleia Luso-Espanhola de Geodesia e Geofísica, Valência, Spain, 4-8 February 2002.
- FERNANDES, M. J. (2002) – “*Satellite Altimetry Data Recovery In Coastal Regions*”, Actas da 3<sup>a</sup> Assembleia Luso-Espanhola de Geodesia e Geofísica, Valência, Spain, 4-8 February 2002.
- L. BASTOS, M. J. FERNANDES, P. TOMÉ, T. CUNHA, S. CUNHA (2002) – “*Combining airborne gravimetry and satellite altimetry for regional tectonic studies*”, Proceedings of The Eleventh General Assembly of the WEGENER Project, WEGENER 2002, Athens, Greece, June 12-14, 2002.
- M. J. FERNANDES (2002), “*Aplicações integradas da altimetria por satélite com altimetria e gravimetria aérea*”, Conferência de Detecção Remota, Lisboa, 4 de Junho de 2002.
- M. J. FERNANDES, L. BASTOS, and P. TOMÉ (2002), “*Evaluation of the potential of gravity anomalies from satellite altimetry by merging with gravity data from various sources – application to coastal areas*”, XXVII General Assembly of the European Geophysical Society, Nice, France, 20 – 26 April.
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- FONSECA, J. F. B. D., FARIA, B. V. E., LIMA, N. P., HELENO, S. I. N., LAZARO, C., OREYE, N. F., FERREIRA, A. M. G., BARROS, I. J. M., SANTOS, P., BANDOMO, Z., DAY, S. J., OSÓRIO, J. P., BAIO, M. and MATOS, J. L. G. (2002), “*Multiparameter Monitoring of Fogo Volcano*”, *JVGR* (Accepted for publication).
- NEKRASSOV, A. and OSÓRIO, J. P. (2002), “*Absolute and Relative Measurements of the Sea Surface Wind Vector by an Airborne Altimeter*”, OCEANS 2002 IEEE/MTS Proceedings, pp. 1987-1993.
- NEKRASSOV, A. V. (2002), “*On airborne measurement of the sea surface wind vector by a scatterometer (altimeter) with a nadir-looking wide-beam antenna*”, IEEE Transactions on Geoscience and Remote Sensing, 2002, Vol. 40, N<sup>o</sup>. 10, pp. 2111-2116.
- NEKRASSOV, A. V. (2002), “*Measurement of the sea surface wind vector by an airborne microwave radar altimeter at low speed of flight*”, Proceedings of APMC 2002, Kyoto, Japan, 2002, pp. 1130-1133.
- OSÓRIO, J. P. (2002), “*Satellite Positioning and Navigation – GNSS*”, Hebei Academy of Sciences, China, January 2002.
- OSÓRIO, J. P. (2002), “*Posicionamento e Navegação por Satélite*”, Rotary Clube do Porto, Maio 2002.

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- OSÓRIO, I. (2002), "GNSS Applications – Applications Unique to Specific Regions – Africa", <http://webconferences.itu.int/gnss>, ONU, Viena, Austria, 2002.
- FERNANDES, R.M.S., J. M. MIRANDA, J. CATALÃO, J. F. LUIS, L. BASTOS, B.A.C. AMBROSIUS (2001) - "Coseismic Displacements of the  $M_w=6.1$ , July 9, 1998, Faial Earthquake (Azores, North Atlantic)". **Geophysical Research Letters**.
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## 7 – OBSERVATÓRIO ASTRONÓMICO PROF. MANUEL DE BARROS DA UNIVERSIDADE DO PORTO

### 7.1 – INTRODUCTION

The activities developed in the Astronomical Observatory “Prof. Manuel de Barros” during the period 1999-2002 comprise several research domains emphasizing, among others, projects developed (or under development) in the following areas:

- Positioning and Navigation by Satellite
- Satellite and Aerial Altimetry
- Aerial Gravimetry using a GPS/INS system
- Remote Sensing
- Geographic Information Systems

Being the domains for the application of the methodologies and algorithms developed very much diversified, some examples are pointed out: geophysical and geodynamical studies, environment monitoring including pollution spots and coastal zones monitoring, oceanographic studies, traffic flow monitoring, cartographic production.

In the following chapter are listed the projects developed in collaboration not only with other universities and Portuguese scientific institutions but also with several foreign institutions with renown in their areas of speciality.

### 7.2 – RESEARCH PROJECTS 1999-2002

*COastal zones monitoring using remote sensing SATellite data*

*A study of the potential use of medium resolution Satellite data for the Detection And Monitoring of Oil Spill events at sea*

*Remote Sensing Applied to Fisheries Monitoring in the Cabo Verde Region*

*Deformation Partition in Azores using interferometric SAR images*

*GPS INformation for Analysis of Traffic Flow*

*Natural Hazards Associated with variations of the Sea Level (Riscos Naturais Associados a variações do Nível do Mar – RIMAR)*

*Airborne Geoid Mapping System for Coastal Oceanography – AGMASCO*

*Long Range and Precise Aerial Navigation System using Real Time DGPS (Sistema de Navegação Aérea de Precisão e Longo Alcance Utilizando DGPS em Tempo Real – SNAP)*

*Geodetic Methods for the study of the Seismotectonics in the South Portugal and Azores-Gibraltar Regions (Métodos Geodésicos para o estudo da Sismotectónica da região Sul de Portugal e da região Açores-Gibraltar)*

### 7.3 – OTHER ACTIVITIES

During this period the Observatory gave logistic and technical-scientific support to 10 Doctoral students, 6 Master students, e 5 research students. Two of the Doctor students concluded their thesis entitled:

“Integrating Inertial and Satellite Navigation Systems for Aircraft Attitude Determination”, Phillip Tomé, Universidade do Porto, 2001.

“High Precision Navigation Integrating Satellite Information – GPS- and Inertial System Data”, Telmo Cunha, Universidade do Porto, 2002.

Researchers related with the Observatory participated in the following Commissions:

EOSS (European Sea Level Observation System, COST Action 40) – Action Management Committee; Sub-commission WEGENER of Commission XIV of the International Association of Geodesy - Presidency;

IAG Special Study Groups of the International Association of Geodesy – National Representation

## 7.4 – COLABORATION WITH OTHER INSTITUTIONS

### **International**

Institute of Geodesy and Navigation, University FAF, Germany  
Finnish Geodetic Institute, Finland  
GeoForschungsZentrum, Germany  
Alfred-Wegener-Institute, Germany  
National Survey and Cadastre, Denmark  
Institute of Solid Earth Physics, University of Bergen, Norway  
Real Observatorio de la Armada, Cadiz, Spain  
Universidad de Madrid, Spain  
Technical University Delft  
University College London, U.K.  
Universita di Bologna, Italy  
Southampton Oceanographic Centre  
University of Dundee  
Spectra Vision, TerraSat, Germany

### **National**

Department of Mathematics, University of Coimbra  
Department of Mathematics, University of Beira Interior  
Department of Mathematics, Faculty of Sciences of the University of Lisboa  
Department of Geosciences, University of Açores  
Department of Geosciences, University of Aveiro  
University of Algarve  
University of Évora  
Faculty of Engineering, University of Porto  
Instituto Geográfico e Cadastral (National Mapping Agency)  
Instituto de Investigação Científica Tropical (Tropical Scientific and Research Institute)  
Força Aérea Portuguesa (Portuguese Airforce)

## 7.5 – COMMUNICATIONS AND PUBLICATIONS (1999-2002)

- BAPTISTA, P.; BASTOS, L.; BERNARDES, C.; DIAS, A. (2002) – “*Monitorização de litorais arenosos*”, Submetida para publicação nas Actas III Conferência Nacional de Cartografia e Geodesia, Aveiro, Dezembro de 2002.
- SOARES, ANA; BASTOS, LUÍSA ; PIRES DA COSTA, AMÉRICO; CUNHA, SÉRGIO; RODRIGUES, CARLOS (2002) – “*Desenvolvimento de um sistema para aquisição de informação sobre fluxo de tráfego*”, Submetida para publicação nas Actas III Conferência Nacional de Cartografia e Geodesia, Aveiro, Dezembro de 2002.
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- LEITE, F. B.; MORUJÃO, D.; BASTOS, L.; FERNANDES, M. J. (2002) – “*Estimação de acelerações usando medidas GPS de fase: aplicação em gravimetria aérea*”, Comunicação apresentada na III Conferência Nacional de Cartografia e Geodesia, Aveiro, Dezembro de 2002.
- BASTOS, L. AND R. M. S. FERNANDES, (2002) - “*WEGENER-GEODAC: Centro de Análise e Base de Dados Geodinâmicos, in portuguese*”. Poster apresentado nas Actas III Conferência Nacional de Cartografia e Geodesia, Aveiro, Dezembro de 2002.
- NAVARRO, A., J. CATALÃO, R. M. S. FERNANDES, J. M. MIRANDA AND L. BASTOS, (2002) – “*Monitorização da Deformação da ilha terceira (AÇORES) com base em observações GPS, in portuguese*”. Comunicação apresentada na III Conferência Nacional de Cartografia e Geodesia, Aveiro, Dezembro de 2002.
- CUNHA, S., BASTOS, L., CUNHA, T., TOMÉ, P. (2002) – “*Tightly Coupled GPS and Dead-Reckoning Navigation for Fleet Management Applications*”. Presented at the conference ION GPS 2002, Portland, USA, September, 2002.



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- FERNANDES, R.M.S., L. BASTOS, B.A.C. AMBROSIUS, R. NOOMEN, W. SIMONS, J.M. MIRANDA AND W. SPAKMAN, (2002) – “*Defining the plate boundaries in the Azores region*”. Electronic publication of the proceedings of 11<sup>th</sup> General Assembly of the Wegener Project, Athens, Greece, June, 2002.
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