S&T Results and Foregrounds

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[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm ; logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

Description of the main S&T results/foregrounds (max 25 pages)

The work performed during the SOFIA project led to the accomplishment of all foreseen project objectives. The GeoMatLab's international visibility has been significantly enhanced leading to the establishment of strategic partnerships with European (i.e., SOFIA Partnering Organizations, European Space Agency, CNES (French Space Agency), Danish Technical University, Danish Space Center) and international Institutes (i.e., Indian Space Research Organization, First Institute of Oceanography-China, Chinese Global Navigation Satellite Systems Center-Wuhan University, China). The research capacity of GeoMatLab has been built up by its research staff and the established infrastructure is capable and ready for cutting-edge research on satellite altimetry calibration and ground deformation monitoring. The Laboratory now possesses a research infrastructure that is unique not only in regional/national but also at international level. To this end, the established scientific excellence of the GeoMatLab research team in conjunction with the developed infrastructure led to overcome its disadvantage of being located in a convergence European region and achieve results that match those performed at research institutes located in more advanced countries.

The scientific and technological results accomplished during the 42 months of this Project duration can be grouped into: a) infrastructure modernization and up-scaling, and b) research capacity enhancement. These S&T results have been properly disseminated into public and private entities and stakeholders (a description is given in the next Section) and their exploitation is expected to secure funding of the GeoMatLab activities for the upcoming years.

The following Sections describe in detail the scientific and technological results of the SOFIA project, as well as the activities performed that allowed the establishment of strategic partnerships.

1. Infrastructure modernization and up-scaling

The developed infrastructure has been distributed at several sites over Gavdos and west Crete, Greece (Figure 1). The Operations Control Centre is located in the TUC's campus and has been developed for fast and efficient processing, as well as for data archival, and for controlling the field units. Next to the Operations Control Center also exists a permanent and continuously operating Global Positioning System (GPS) station, named "TUC2", operating as of 2003 (Figure 2). This station is part of the European Permanent Network for EUREF. A new EGNOS station, coined "TUC3", has been installed in the University Campus and is the first EGNOS site in Greece (Figure 3). TUC3 is collocated with a BeiDou/Compass chinese satellite station (TUC4). BeiDou is the Chinese navigation system and this TUC4 site is the first one to be installed in Europe. Collaboration with the Chinese GNSS Research Center, Wuhan University, China, made this installation possible. GeoMatLab personnel are currently trained by Chinese researchers in processing BeiDou satellite data with the PANDA software.

The main satellite calibration facility is located at Gavdos island; on land property, bought by the University for the needs of satellite calibration. The Gavdos calibration facility includes the "Karave" (tide gauges, meteo sensors, GPS, etc.) on the harbour, the "Theophilos (central communication site and control)" and the "DIAS" sites (transponder) (Figure 4). The RDK1 site on the south Crete is considered to be a secondary Cal/Val site, because it has been installed along the north part of the ground track of the Jason satellites (Figure 5). In south west Crete, the Chrysoskalitissa site (CRS1) has been upgraded and is currently a fully-equipped Cal/Val site (GNSS receiver, main and back-up tide gauge, meteorological sensors, etc.) ready to be used for the calibration of the Jason series and the Chinese HY-2 satellite altimeter (Figure 6).

The deformation monitoring network in west Crete has been also enhanced through the establishment of the SUG1 GNSS site in south west Crete (Figure 7). This SUG1 site, as well as the previously established sites at “Petra Seli” and “Menies” (SEL1 and MEN2, respectively) concluded the GNSS network for monitoring any velocity transient effects and other phenomena of the earth’s crust at the subduction zone in Crete. All these GNSS sites have been upgraded with the state-of-the-art, reliable, and accurate scientific instrumentation.

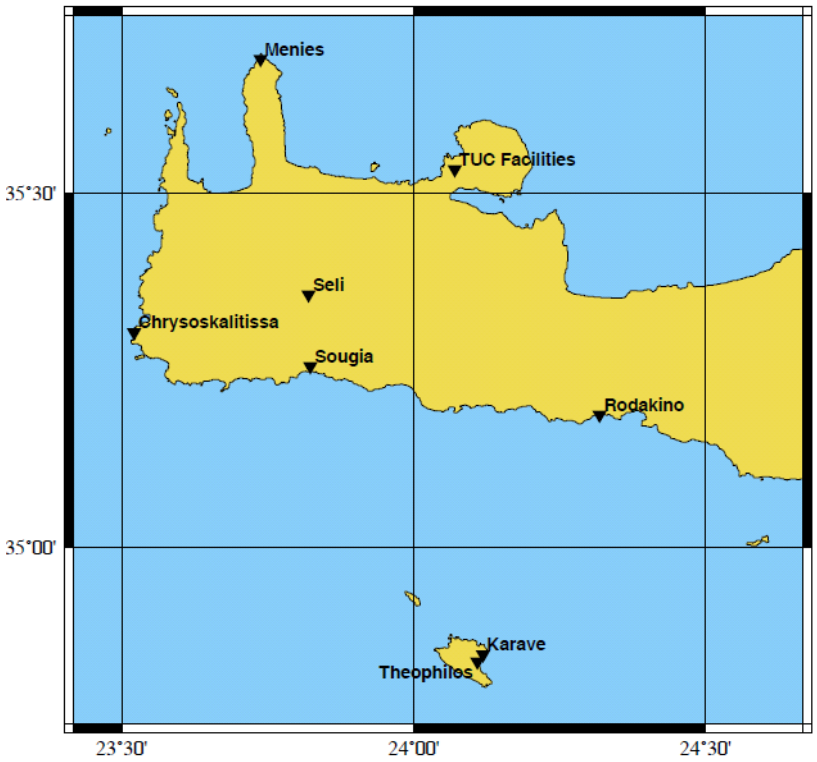

Figure 1. The TUC instrument site locations in western Crete and Gavdos Islands.

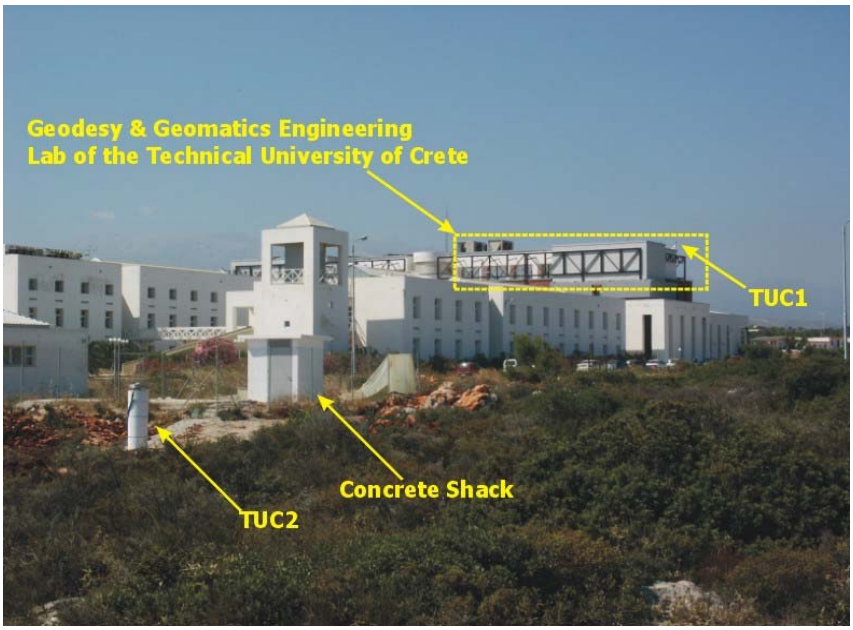

Figure 2. The TUC2 Global Navigation Satelite System site, called TUC2, on the Technical University of Crete Campus. This is also part of the Permanent European Network..

Figure 3. The "TUC3" Global Navigation Satelite System site of the European EGNOS (left) and the TUC4 BeiDou/Compass (right)chinese receiver sites at TUC facilities on campus.

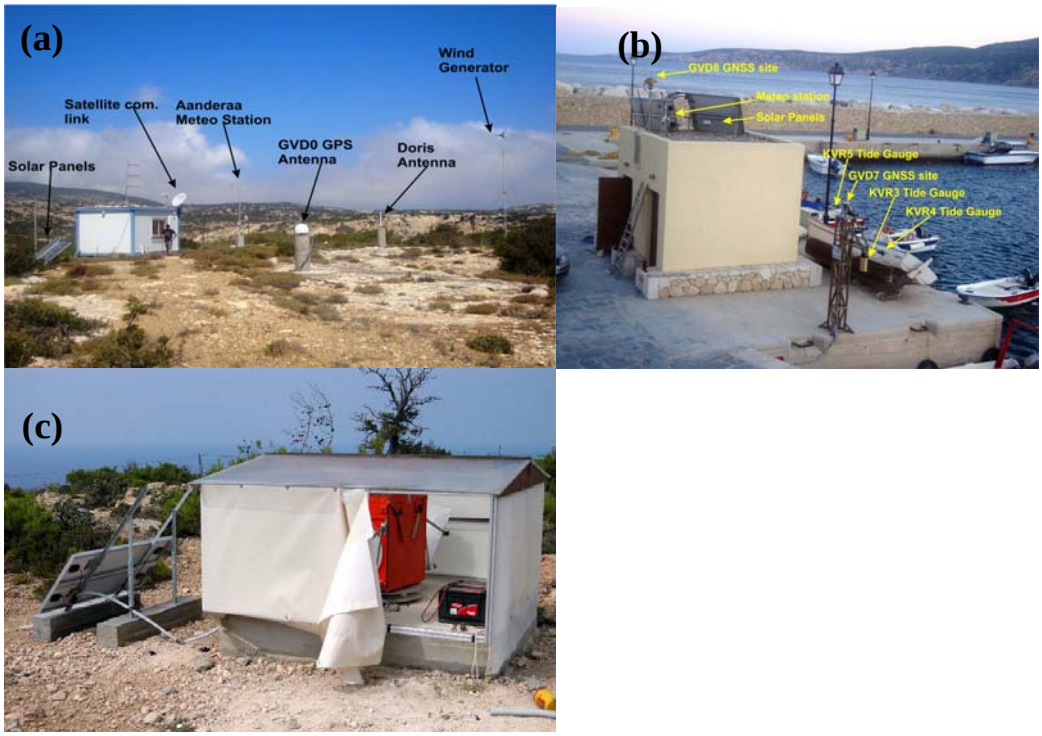

Figure 4. The main satellite calibration facility in Gavdos. (a) The "Theophilos" main site on the main land of Gavdos, (b) The Karave site at the Gavdos harbor, and (c) the "Dias" site at the cross-over location of the ascending and descnding orbits of Jason satellites on the Gavdos isalnd.

Figure 5. The instruments installed at "Rodakino" site, at a location along the ascending orbit of Jason satellite on the centarl west coast of Crete.

Figure 6. The instruments installed at "Chrysoskalitissa" site (CRS1) on the south west Crete.

Figure 7. The "Menies" (MEN1), "Seli" (SEL1), and "Sougia"(SUG1)Global Navigation Satelite Systems permanent sites used for crustal deformation monitoring.

The basic equipment and software that has been purchased, installed and operarate during the SOFIA project is as follows:

- *Three GNSS receivers*. The first one is a receiver capable to lock data from the European Geostationary Navigation Overlay System (EGNOS) and the other two are state-of-the-art units that replaced the old ones operated for several years. More specifically the EGNOS receiver has been installed inside TUC campus in a remote area dedicated for the development of the first EGNOS Data Collection Station in Greece. One of the new receivers replaced the old one operated at the TUC2 site (now transferred and installed at the "Rodakino" site in south Crete) while the second one (GVD8) replaced the one operated at the Gavdos "Karave" site (GVD5);
- *Six tide gauges*. Four of them have been installed at the main satellite calibration location in Gavdos, i.e., "Karave" site, while the other two have been set-up at the "Chrysoskalitissa" site in southwest Crete. More specifically, at the "Karave" site a pressure tide gauge (KVR5), an acoustic tide gauge (KVR4) and a radar tide gauge (KVR6) have been installed and are fully operational. The later tide gauge (KVR6) has been setup inside the "Karave" concrete shack in the Gavdos harbor, where inside it there exists a well for reliable sea level measurements. This installation has been carried out to have a protected sea level measuring system that will not be influenced by weather conditions, and thus it will provide reliable measurements for the sea surface height. On-site calibration of the sea-level measurements obtained by these tide gauges will be made by a staff gauge also installed there at the harbor. In south west Crete, the Chrysoskalitissa Cal/Val facility has been equipped with one pressure (SVR1) and one radar tide gauge (SVR2). This site will be used for the calibration of the Chinese HY-2 satellite altimeter and is expected to play a dominant role in future GeoMatLab's scientific and research activities. It will be the first time that this Chinese satellite altimeter will be calibrated by a European institute and outside China;

- *Three meteorological sensors*. For the "Chrysoskalitissa" and Gavdos "Karave" sites meteorological sensors, directly connected directly to GNSS receivers (thus ensuring data transfer through GNSS raw data), have been purchased and installed. Additionally, the old meteorological sensors installed at the Gavdos "Theophilos" site have been re-calibrated in the Lab and replaced, when damaged;
- *One choke ring GNSS antenna*. This has been installed at the "Chrysoskalitissa" CRS1 GNSS site in GeoMatLab's effort to improve precise geodetic positing at this site to meet the satellite altimeter calibration standards;
- One prototype instrument for monitoring ionospheric scintillations;
- *Software for GNSS data processing*. GeoMatLab is now performing GNSS data processing using different software. The newly acquired software (BERNESE) can produce Total Electron Content estimates for the ionosphere.
- *Batteries* for operation of the GPS buoys, used for measurement of the sea surface height simultaneously when the Jason-2 satellite was flying over the boat at sea. These buoys are property of the Hellenic Centre for Marine Research but were lend to the Lab for the purpose of this Project.
- Modems, cables and other peripherals for the communication links. Currently there are two satellite links (at Gavdos "Theophilos" and "Chrysoskalitissa" sites) and two mobile telephone GPRS connections (at Gavdos "Karave" and "Rodakino" sites).
- One file-server main computer. This computer has been placed in a protected environment at the major TUC's Data Center on Campus, and is used for data archival, data base operation, data processing, etc;
- Two personal computers and notebooks with their peripherals. These computers were by the Project Secretariat and the recruited post-doc researchers, while the notebooks have been used in the field for in-situ data downloading.
- Software upgrade for remote, automated GNSS data management;
- Solar panels and accessories for power supply at the "MEN1" GNSS site as well as the EGNOS site;
- Replacement of the batteries used for power supply of the Gavdos main facility;

The current state of the GeoMatLab's infrastructure is presented in the following Sections.

1.1. TUC Campus Facilities

The instrumentation installed at TUC Campus facilities are:

- A Leica GNSS 1200+ receiver (named TUC2) along with a Vaisala PTU 200 meteorological station.
- A PolaRx3eGPRO EGNOS/GPS station (called TUC3).
- A UNICORE UB240 CORS Compass/GPS station (called TUC4).

The TUC2 station is installed inside a concrete shack close to the GeoMatLab's facilities. TUC2 is part of the European Reference Frame (EUREF) regional GNSS network since 2004. Its data are available on line in the internet as part of the permanent European GNSS net (http://www.epncb.oma.be/_trackingnetwork/siteinfo4onestation.php?station=TUC2). TUC2 station provides to EUREF hourly and daily GPS (American) and Glonass (Russian) data as well as meteorological measurements. Users can access data through the EUREF ftp servers (ftp://igs.bkg.bund.de/EUREF/obs/2010).

The TUC3 is installed inside a different concrete shack close to the Laboratory's facilities on Campus. TUC3 station is operated as a permanent GNSS station and therefore must follow the IGS (International GNSS Service) standards for CORS (Continuously Operating Reference Stations). This is also part of the EGNOS (European Geostationary Navigation Overlay Service) data collection network.

TUC4 station is the first European GPS/Compass GNSS station (Compass/BeiDou is the Chinese satellite navigation system). The receiver is temporarily installed on the roof of the Laboratory building for training and easy access.

A Meteorological sensor (Vaisala PTU200) is directly connected to the TUC2 GNSS receiver using a serial cable. In this way, the GNSS receiver acts as a data logger for the meteorological sensor. Measurements are stored in the widely used meteorological RINEX format inside the satellite receiver. The GNSS receiver is accessed using a TCP/IP interface (The university LAN network is accessible inside the concrete shack).

1.2. Gavdos Cal/Val facility

The following instruments have been installed at the Gavdos Cal/Val facility within the framework of the SOFIA project:

"Karave" site at the Gavdos harbor

The "Karave" site in Gavdos is the main site used for satellite altimeter calibration at the harbor. The instruments installed there are:

- A Leica GNSS receiver, called GVD7A Paroscientific MET4 meteorological sensor, attached to the GVD7 receiver;
- A back-up Leica GNSS receiver (GVD8). This state-of-the-art receiver measures the American GPS and the Russian Glonass signals as well;
- An OTT Kalesto radar tide gauge (KVR3)
- A General Acoustics LogALevel backup tide gauge (KVR4)
- A Valeport tide master pressure tide gauge (KVR5);
- A Vega radar tide gauge (KVR6);
- A staff gauge for onsite calibration of the sea-level measurements made by all "Karave" tide gauges in the Gavdos harbor;
- A LINUX downloading heavy-duty computer.
- A GPRS communication link.

All sensor measurements (except KVR3) are downloaded daily and archived at the "Thales" main file-server computer in the University Campus in Chania.

"Theophilos" central site in Gavdos

The "Theophilos" site in Gavdos is the main satellite calibration infrastructure on Gavdos Island. All instruments placed there are located at a 4,000 m^2 plot owned by the Technical University of Crete. Originally when there was only a poor UHF data connection to the island, all data transmissions where tunneled through "Theophilos" site at the Gavdos harbour and then to the University facilities in Crete.

The instruments installed are:

- A Leica RS500 GPS Receiver along with a Leica AT504 GPS choke ring antenna comprise the "GVD0" GNSS site;
- An Aanderaa Automatic weather station has been calibrated in the Lab and replaced;
- A DORIS Satellite beacon along with a Vaisala PTU200 meteorological station. (Owned and operated by CNES, France)
- An industrial computer as well as the other sensors installed at this Gavdos Central facility;

"Dias" transponder site

The "DIAS" site in Gavdos is located under the crossover of Jason satellite Passes No 018 & 109. The old microwave transponder (property of the Austrian Partnering Organization) has been installed there since 2003. Under the framework of the SOFIA project, several GPS and geodetic leveling surveying have been conducted for a) determination of the transponder's absolute ellipsoidal height, and b) estimation of the atmospheric delay parameters (wet troposphere and ionosphere) for correcting Jason-2 satellite altimeter measurements. The transponder has been disassembled and shipped from Gavdos to CNES French Space Agency in Toulouse for examination, calibration, and upgrading in June 2012. The site is to be occupied by the newly developed TUC transponder for the calibration of Jason satellites.

1.3. Rodakino Cal/Val facility: RDK1

The "Rodakino" Cal/Val facility is at the south central coast of Crete and under the ground track of the Jason's Pass 109. This facility serves as a back-up satellite calibration site and has been used to verify the altimeter bias results obtained by the Gavdos Cal/Val facility for the determination of the Jason-2 satellite.

A radar tide gauge station ("RDK1", type: Vegapuls-61) with its accompanying data logger (Vegamet-624) and a Leica (Smart 6200) GPS receiver had been initially installed at Rodakino site on 6 March 2009. The GNSS receiver was then replaced with a Leica GRX1200GG PRO receiver and a Leica AT504 choke-ring antenna to enhance the site's performance. Data are transferred to the Operations Control Center in the University Campus via GPRS communications link.

1.4. Chrysoskalitissa Cal/Val facility: CRS1

A Leica GRX1200GG PRO GNSS receiver along with a Leica AX1202 GG antenna has been operating at "Chrysoskalitissa" site since 8 March, 2008. A Vaisala PTU300 meteorological sensor was installed on March 5 2010. A pressure tide gauge station (Valeport Tidemaster) has been installed on April 25 2012 (CRS1). An OTT RLS radar tide gauge was installed at "Chrysoskalitissa" site on June 2012 (CRS2). Data from this field measuring units are transferred via a satellite communication link to the Operations Control Center at GeoMatLab.

The "Crysoskalitissa" site will serve as the main calibration facility of the Chinese HY-2 satellite altimeter.

1.5. Other GPS sites for crustal deformation monitoring

GeoMatLab has installed three GPS sites in collaboration with the North Carolina State University, USA, along the direction of the North-South axis in Crete. These sites are equipped with Trimble NetRS GPS receivers and Trimble Zephyr Geodetic GPS antennas. "Menies" (MEN1) site was installed on 20 November, 2009 but was vandalized on 27 December, 2009. A new installation and a safer location has been chosen close and the station has been re-installed (MEN2). The Seli (SEL1) site in the central west Crete was installed on 10 July, 2009. The Sougia (SUG1) site in the south west Crete was installed on 5 November, 2010. The Technical University of Crete and the North Carolina State University, USA have signed a Memorandum of Understanding for scientific collaboration that led to the installation of three GPS receivers at the North-South axis of western Crete.

In order to be able to install and maintain these instruments at these remote field locations, several field trips have been carried out. For each field trip, a Traveling Report has been written and submitted. Moreover, details regarding the technical characteristics, operational

capabilities, data storage and archival of the GeoMatLab instrumentation are provided in DL2.1, and its respective Annexes. This Section presented in detail the work conducted during the reporting period in terms of instrument maintenance, infrastructure upgrading, etc. All this work has been conducted under the framework of SOFIA project WorkPackage 2, Task 2.1.

1.6. Development of a prototype microwave transponder

The infrastructure presented in Sections 1.1-1.5 is considered to be the conventional equipment for the establishment of satellite altimetry calibration facilities and GNSS network for crustal deformation monitoring. During the SOFIA project, GeoMatLab was able to deliver a prototype microwave transponder to serve as an alternative and independent technique for calibration of satellite altimeters (Figure 8).

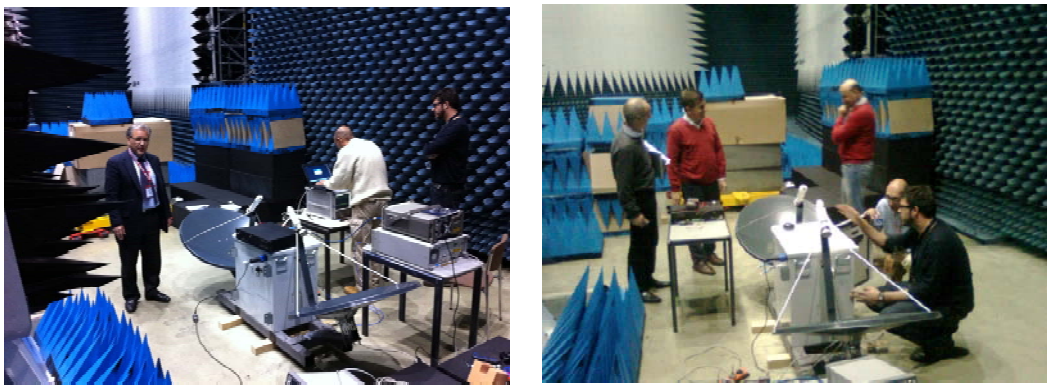

Figure 8. *The prototype microwave built in this Project at the Compact Payload Test Range facilities in the European Space Agency, Noordwijk, the Netherlands in 2012.*

Microwave transponders have been proposed as an alternative tool for satellite altimetry calibration more than 10 years now. However, in the world, only few transponders have been built and implemented for this reason. In Europe there are only two active transponders: one is located in European Space Agency Observatory in Svalbard, Norway (more than 20 years old, mainly used for the Cryosat-2 calibration) and another old transponder in the Gavdos Cal/Val facility (more than 15 years old, property of the Austrian Partnering Organization). A microwave transponder is considered to be a stable and sharp calibrating target on the ground when the satellite flies over it, but it acts as if it were on the sea, yet with known properties. It receives, amplifies and retransmits, with minimal distortion, a satellite radar altimeter signal, which in turn is recorded on-board the satellite. The two-way travel time of the signal, after corrections for the atmosphere delays and tides, yields the range between satellite and transponder. This transponder can thus be used to calibrate the range measured by the satellite to the earth, the signal delays in the atmosphere and the effective cross section (sigma-naught) of the reflection in nadir-looking altimetry.

Under the framework of the SOFIA project, a prototype transponder has been constructed mainly for the calibration of the European Cryosat-2 and Sentinel-3 altimetric missions. As mentioned before the operation of a transponder relies on the reception by the satellite of an amplified signal produced by the transponder on land. However, satellite altimeters have specific thresholds in the signal's power reception capability. If the satellite receives a signal above certain thresholds then it will be destroyed its sensors and possibly causing a damage of several million euros to the operational agency; in our case the European Space Agency. For this reason the specifications as well as the construction phases of the new ptototype transponder were set, specified, examined, and monitored by the responsible personnel (managers and technicians) for Cryosat-2 and Sentinel-3 missions in the European Space Agency.

The technical specifications of this new prototype instrument have been defined through joint efforts of GeoMatLab, ESA, CNES and the Austrian Partnering Organization. An invitation to tenders for the instrument manufacture had been then published in August 2009.

PRISMA Electronics SA is the industrial company, awarded the construction of the new transponder. Regular exchange of emails and teleconferencing between PRISMA, GeoMatLab and ESA, have been performed for continuous monitoring and review of the transponder manufacturing progress and to define technical details, not given at the initial technical specifications documents. Besides this communication exchange, meetings with ESA personnel in the Netherlands also took place.

A meeting at the European Science and Technology Center, ESA in Noordwijk, the Netherlands, took place on 26th August 2010 with representatives from ESA, PRISMA and GeoMatLab. The main purpose of this meeting was to monitor and review the progress on the transponder design/test/performance, but also cover some aspects about the location and the setting around the proposed calibration site in Crete.

The transponder has been delivered to TUC on 10 November 2010, however testing of its operational capabilities into simulated or real life conditions had to be conducted. There was a significant delay for the implementation of these tests, mainly due to the need for including some extra electronics parts and monitoring sensors inside the transponder. Moreover, there was a continuous inspection on the optimum transponder assembly, regarding the orientation of the transponder's antennas and the way they were supposed to be placed outside the transponder itself. After a series of modifications and adjustments, the final transponder assembly with the mounted antennas has been agreed upon by ESA and finally manufactured by PRISMA private company.

Calibration and validation of the transponder itself, under simulated in-house conditions has been conducted at ESTEC/ESA specialized chambers in Noordwijk, the Netherlands. These specialized, in-house tests have been performed from March to June 2012. A meeting in ESA was arranged on March 2012 to evaluate the performance and review the newly developed prototype microwave transponder. The meeting took place in the ESA premises in Noordwijk, the Netherlands on Thursday 8-March-2012 and Friday 9-March-2012. In the meeting, a science team from ESA (Dr. Mavrokordatos, Dr. Borde and Dr. Rolo), a delicate of the manufacturing company, Prisma Electronics (Mr. Komninos) and the SOFIA Project Coordinator participated. During the tests conducted in ESTEC in the Netherlands, several problems have been encountered and resolved by ESA personnel. Finally, the transponder has successfully passed all calibration and verification tests and delivered to GeoMatLab in Crete in June 2012. Thus, Task 2.2 of the SOFIA project has been successfully accomplished.

2. Enhancement of GeoMatLab's research capacity

Section 1 presented the modernization and up-scaling of GeoMatLab's infrastructure as well as the construction of a prototype transponder instrument for satellite altimeter calibration. The existence of high-tech instruments is a precondition for the performance of cutting-edge research especially in engineering disciplines like satellite altimetry, satellite navigation systems and deformation monitoring. However, this is not enough and the researchers assigned to perform this Project research had to be well qualified. A main disadvantage of GeoMatLab is the difficulty to recruit experienced researchers because of its location at a convergence European region and the fact that the financial resources available are far less than in other more advanced countries.

To this end, GeoMatLab used the resources available from the SOFIA project to a) recruit two experienced researchers, and b) to build up the research capacity of existing team

members. The latter was successfully performed through the exchange of know-how with the, the Indian Space Research Organization, The Jet Propulsion Laboratory, in the USA, the Chinese Research GNSS Center in Wuhan, The First Institute of Oceanography in Quigdao, China and certainly with the SOFIA partnering organizations, as well as the participation of GeoMatLab personnel in international conferences, workshops and training events. The following Sections will present the main results obtained during the SOFIA project lifetime in terms of improvement of GeoMatLab's research capacity.

2.1. Recruitment of experienced researchers

Two experienced (post-doc level) researchers have been recruited under the framework of the SOFIA project: one to enhance satellite altimetry calibration procedures and instruments and another to carry out research signal deformation monitoring methodology and software development.

One of the main activities in the GeoMatLab group is the calibration/validation of altimetry satellites. Such a work requires the development of algorithms that are using the data from the altimetry satellites, the data processing of GPS and the easy access and processing of data coming from on-site sensors, such as tide gauges. GeoMatLab installed a number of GPS stations and tide gauges in the Gavdos and south Crete areas which provided the required data to validate and expand the work on the satellite altimetry calibration and validation.

During the SOFIA project, improvement of existing and development of new algorithms in the satellite altimetry calibration/validation as well as the design and development of a software suite (called "TUCaliBrit") were the main achievements regarding satellite altimetry calibration. This software uses data from the instruments installed at Gavdos facility (tide gauges, GPS receivers, meteorological sensors, etc.), apply several models (i.e., the marine geoid models, Mean Sea Surface, regression, filtering and prediction models) as well as the results from the GPS processing to determine the altimeter bias and corrections for other parameters of satellites flown over Gavdos. Currently, the user of "TUCaliBrit" has the possibility: i) to select among various marine geoid, mean sea surface and mean dynamic topography models, ii) to initialize the newly developed wet tropospheric model for coastal regions, as provided by Shannon Brown et al., and iii) to statistically analyze the extracted calibration results in order to choose the appropriate procedures and models that best fit the Gavdos Cal/Val local conditions.

The results obtained by the calibration methodology employed in Gavdos Cal/Val facility have been presented at relevant workshops (e.g., Ocean Surface Topography Science Team, Coastal Altimetry Workshops, etc.) as well as in scientific journals (i.e., Marine Geodesy, Advances in Space Research). The Gavdos Cal/Val facility has a proven record for reliable estimates of bias values in the satellite altimeters, which are in accordance with the values reported by the other three international calibration sites in the USA, France, and Australia.

Besides the conventional sea-surface calibration methodology, GeoMatLab also developed, in collaboration with ESA, CNES and the Austrian Partnering Organisation, a software suite for the determination of the Jason-2 satellite employing the existing Gavdos transponder. This software will serve as the main processing tool to analyze the data obtained by the newly developed prototype transponder.

Furthermore, through the collaboration with other Greek (i.e., Aristotle University of Thessaloniki, University of Aegean) and European (i.e., Danish Technical University) institutes the development of local geoid and mean sea surface models, to be applicable in Gavdos, was realized. These local reference models tend to reveal possible correlations between satellite altimetry data and sea floor bathymetry at the centimetre level. Also, the use of altimetric measurements for monitoring ionospheric disturbances caused by tectonic

motion is under investigation at the subduction zone. This work is expected to be finalised in 2013.

Monitoring of tectonic motion present in the area of Crete was one of the main objectives of the second post doc researcher. To accomplish this Task the first step was to perform accurate, precise and reliable analysis of the GPS data obtained by the TUC-net GNSS network. During this reporting period this was feasible through the processing of geodetic data using 3 different scientific software (i.e., GAMIT, Bernese, GIPSY) that allow accurate determination of each station coordinates and the respective 3-dimensional rate of their movement.

Time series analysis of the data obtained by the GNSS array in Crete made feasible to identify long-range, power-law correlation in these geodetic data. Abrupt change detection algorithms for the identification of weak signals (possibly related to silent earthquakes) have been also developed and implemented in GeoMatLab's TUC-net geodetic data.

2.2. Exchange of know-how with partnering organisations

The SOFIA partnering organisation were: the Austrian Academy of Sciences (SRISG), Austria, the Observatoire de la Cote d' Azur (OCA), France, the Deutsches Geodatiches Forschungsinsitut (DGFI), Germany and the GeoForschungsZentrum Potsdam (GFZ), Germany. The exchange of know-how with these well-established European entities was performed through dedicated visits, exchange of emails and teleconferences, meetings and organization of international conferences/workshops.

The main result of the collaboration between GeoMatLab and SRISG has been the development of the software to determine the Jason-2 altimetric bias using the SRISG's Gavdos transponder. This is an important asset in GeoMatLab's research capacity s that the developed technical skills are now to be used to exploit its newly developed, prototype transponder for the Jason-2 altimeter. Moroever, SRISG assisted significantly GeoMatLab to define the technical specifications for the newly developed transponder.

The collaboration between GeoMatLab and OCA-France focused on the conventional sea-surface calibration methodology. Advances on processing algorithms, models and statistical analysis of retrieved data were possible through this collaboration. Also, dedicated boat field campaigns for the determination of the instantaneous sea surface height as well as the geoid undulations slope at the Gavdos area have been conducted following recommendations provided by the OCA Partnering Organisation that has long-term experience in the performance of similar field campaigns.

The German Partnering Organisations assisted GeoMatLab to build up its research capacity in terms of GNSS data processing and crustal deformation monitoring. More specifically, the methodology to determine the wet troposphere and the ionosphere delay using the TUC-net GNSS array has been developed. These products are essential input in both calibration methodologies (sea surface and transponder calibration) employed by the GeoMatLab team. Processing of geodetic data using the Bernese software was feasible after specialised training events conducted by the German Partnering Organisations. Currently, geodetic data are processed by GeoMatLab employing three scientific software (i.e., GAMIT, Bernese and GIPSY) to provide reliable estimation of the coordinates and velocities of the TUC network in West Crete and Gavdos sites as well as the production of continuous time series of geodetic positioning solutions. These products are fundamental inputs for crustal deformation monitoring and abrupt change detection research.

Section 2 presented the work performed during the SOFIA project to enhance GeoMatLab's research capacity. A proof of this statement is corroborated by the GeoMatLab's publications

record during the Project. During this 42 month of the SOFIA project, GeoMatLab's Project work was published in 13 peer-reviewed articles in scientific journals and workshop proceedings. In addition, 17 presentations (oral and poster) have been given at international conferences and workshops all over the world.

Summing Up

The main objective of this "SOFIA" project has been to improve the research capacities of GeoMatLab. This was performed through (1) the modernization of the infrastructure, (2) the development of a new prototype transponder instrument for satellite altimeter calibration, (3) the exchange of know-how with the partnering organizations, (4) recruitment of senior and junior researchers, (5) increase its participation in European research projects and international scientific teams, and (6) enhancement the transition from research to regional social and economic sustainable development.

After the completion of this Project, the methodology and facilities at the Gavdos and Crete for the calibration of satellite altimeters have improved and were made capable to be extended for other international altimetric satellites using alternative and independent techniques, but also newly developed instruments. Collaboration with all partnering organizations that took place during this reporting period have resulted in long-term associations by signing 3 Memorandum of Understandings with the Austrian, German and French Partnering Institutes.

GeoMatLab has built and established its caliber and capacity within the international community and research teams for satellite calibration and deformation monitoring. It also enhanced its research potential and visibility. The dedicated Gavdos and Crete Cal/Val facilities have established as one of the four international satellite calibration sites in the world. Such stature is earmarked by including the Gavdos Cal/Val facility in the presentation, for the dedicated Cal/Val sites in the world, to be given at the "20 years of progress in Radar Altimetry" Symposium, in Venice, Italy, 24-29 September, 2012. The established dedicated Cal/Val site is now fully instrumented to provide an independent (in-situ) determination of sea-surface observations and provide the basis for calibrating the altimetric measurements made by the satellites as they overfly the location. It will provide fundamental calibration information in the centre of the East Mediterranean for an uninterrupted monitoring of the Jason satellite and its successors, as well as the European Cryosat-2, and Sentinel-3 and Chinese and French/Indian missions. Also, the established permanent GNSS network in west Crete and Gavdos is able to monitor crustal deformation in one of the most seismic active regions in Europe on a continuous basis and provide valuable information for earthquake research and interpretation. This site has become essential infrastructure in monitoring sea level variations and climate changes for our planet.

Negotiations with the satellite operators, such as ESA, are under way for funding the establishment of a permanent calibration site for Sentinel-3 in the south west of Crete using the developed transponder. A site with a triple cross over of the Jason, Sentinel-3A & 3B and AltiKa satellites over west Crete has already been identified, tested, and selected. In the same token, a permanent site at CRS1 in southwest Crete is planned for the calibration of the Chinese satellite altimeter.

The Project has also contributed to regional development by unveiling a problem in land subsidence of 2cm/year caused by excessive pumping of groundwater for irrigation in East Crete and by discovering a power-law, and long-range correlation in the observed deformation signals of two GNSS sites. This may have an impact on earthquake research for the region. Finally, local engineers are also using the precise positioning data provided by the established west Crete network of permanent GNSS sites to improve their accuracy and operations cost.