GOCE – ITALY: ORGANIZATION, CONTENTS, PERSPECTIVES

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ABSTRACT

GOCE-Italy is a group including mainly research teams from Universities and has been established to coordinate the research efforts regarding the ESA mission GOCE at the national level in Italy. The GOCE-Italy structure is coordinated by ASI (the Italian Space Agency) and Politecnico di Milano; the units involved are from the Politecnico di Milano and from the Universities of Bologna, Milano, Padova, Pisa and Trento. In this way several "historical" Italian research groups will have the opportunity to play a propositive role in an original research proposal in the field of global gravity model determination.
As it is obvious, all the effort provided by GOCE-Italy has to be seen within the framework of a strict international co-operation structured in the form of the EGG-C Consortium, to which the Politecnico di Milano participates.
In this paper, we will illustrate not only the organization of the GOCE-Italy group, but also the contents of the research work undertaken by the different units and the perspectives which are in front of us in the next few years to come.

INTRODUCTION: WHY GOCE - ITALY

The groups that agreed upon the establishment of the GOCE – Italy co-ordination, had several objectives in mind. We will recall them briefly.

- By joining the efforts of many teams, Italy will have the opportunity to play a role in all the scientific aspects of the mission:
  - design;
  - data archiving and pre-processing, products dissemination;
  - mission data simulation/processing;
  - geodetic analysis of the results (estimate of the field);
  - solid earth geophysical interpretation;
  - oceanographic interpretation.
- As a consequence, Italy, which has significantly funded GOCE, will hopefully have a "visible" role in the project, also bringing out the participation to the mission of the Italian industry, which acts as prime contractor.
- Several "historical" Italian research groups (e.g. Politecnico di Milano and University of Milano, for Aristoteles and STEP studies, etc.) will have the opportunity to play a propositive role in an end-to-end pre-processing chain (integrated space wise - time wise approach), which is an original research proposal in the field of global gravity models determination.
- All the research teams of the GOCE – ITALY group will have the opportunity to fully exploit their competence, commonly achieved over a decade.
- IGeS (International Geoid Service), which is an International IAG Service with premises at the Politecnico di Milano, could be possibly used as an official international instrument to acknowledge the mission product (properly integrated with ground data) as an international reference tool for the earth gravity field.
- Opportunities will be given by a possible follow-on in ESA, since the mission will make new ways to Earth observation and hopefully to planetology applications.

RESEARCH TEAMS OF THE GOCE – ITALY GROUP: COMPOSITION AND COMPETENCE

The GOCE – ITALY group is composed by two different structures (see Fig. 1):

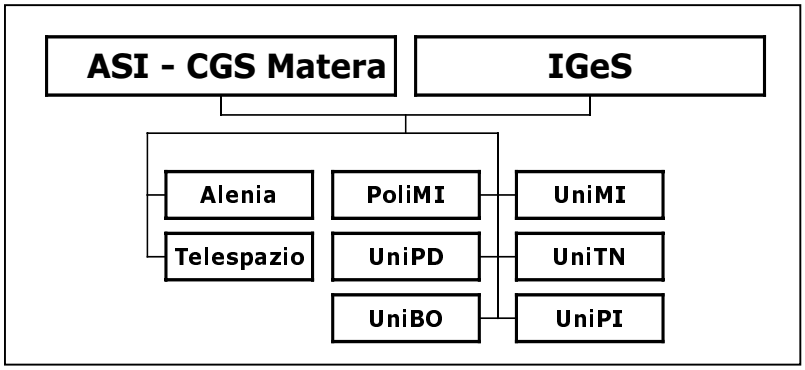

Fig. 1. Structure of the GOCE – Italy group

List of the acronyms:

ASI – CGS	Italian Space Agency – Satellite Geodesy Centre
IGeS	International Geoid Service
PoliMi	Politecnico of Milano
UniMi	University of Milano
UniPd	University of Padova
UniTn	University of Trento
UniBo	University of Bologna
UniPi	University of Pisa

- a structure at the University level, to which groups already interacting will participate (these groups have participated in co-ordination to researches funded by ASI since several years, under the title "Working group on measurements and methods of high precision space geodesy");
- a structure at the industrial level, supported by the CGS (Centro di Geodesia Spaziale) in Matera, which has participated to the researches funded by ASI.

In the framework of the GOCE – ITALY group, the competence of each team would be as follows:

- Alenia Spazio would supply the interface support with the satellite system and the know-how on the on board instruments functioning and performances;
- the role of ASI – CGS Matera would be focussed both on laser ranging problems (one of the mission sub-systems) and on pre-processing and archiving problems;
- Telespazio would be devoted to the actual fulfilment of the data pre-processing chain;
- regarding the University teams, some would be devoted to the study of data pre-processing problems, both in general and specifically for the observation reduction chain with the "space-wise" and "time-wise" approach:
  - UniPd GPS/POD,
  - UniPi iterative solutions in the "time-wise" approach,
  - PoliMi "space-wise" approach,
  - UniTn support to PoliMi activities in the "space-wise" approach;
- other University teams would work on general subjects regarding the multidisciplinary use of the GOCE data:
  - PoliMi geodetic interpretation,
  - UniMi solid earth geophysics,
  - UniBo oceanographic interpretation.

RESEARCH LIFE-TIME AND AGENDA

The specific researches of the GOCE – ITALY group may be supposedly divided into three main phases:

a) from 2000 to 2004: studies, simulations and preparation of the end-to-end pre-processing chain and of the end-to-end interpretation software; in the meantime, training of a group of young researchers expert in GOCE, rewarded under time contracts (e.g. research contracts);
b) from 2004 to 2005: on-the-fly analysis of the data, pre-processing, calibration and data validation;

c) from 2005 to 2007: geodetic analysis of the data, global model (and related studies), solid earth geophysics and oceanographic interpretation.

In general, during the next years the work will follow this agenda:

2000 – 2001 data simulation
2001 – 2002 formal data simulation and interface with Alenia
2002 – 2003 robustness of the solution algorithm with respect to systematic errors
2003 – 2004 chain preparation and final simulation
2004 – 2005 quick-look, calibration and pre-processing
2005 – 2006 data processing
2006 – 2007 processing and interpretation

CONTENT OF THE RESEARCH

The participants to the GOCE – Italy co-ordination have identified six "working lines" in which their research can be subdivided. The titles of these working lines are reported in Table 1, while their contents and subdivision of tasks among the teams are shown in Table 2.

Working line	**Title**
1000	Simulation and simulated data analysis
2000	Calibration
3000	Technological fall-out / Mission analysis
4000	Global field determination
5000	Geodetic / geophysical interpretation
6000	Operational processing / Data archiving

Table 1. Titles of the research working lines in GOCE - Italy

Research line	**Content**	**Research team**
1100	Orbit simulation	UniPi - CGS Matera Telespazio - UniPd
1200	Error simulation	UniPi - CGS Matera Telespazio – UniTn - UniPd
1300	Orbit determination	UniPd - CGS Matera Telespazio - UniPi
2100	Gradiometer physical model	Alenia - UniPd
2200	Gradiometer numerical model	Alenia
2300	Error model	Alenia
2400	Parameter estimation	UniPi - PoliMi
3100	Mission analysis support	Alenia
3200	Calibration	Alenia - UniPi
4100	Time-wise approach	UniPi - UniPd
4200	Space-wise approach	PoliMi - UniTn
4300	Time-wise space-wise iteration	PoliMi - UniPi
5100	Solid earth	UniMi
5200	Oceanography	UniBo - PoliMi
5300	Geodesy	PoliMi
6100	Pre-processing	CGS Matera - Telespazio
6200	Archiving	CGS Matera - Telespazio
6300	Final products	CGS Matera - Telespazio

Table 2. Contents of working lines and subdivision of tasks among the GOCE – Italy teams

SCIENTIFIC CONTRIBUTION OF THE RESEARCH TEAMS

Research team PoliMi
(Politecnico of Milano – DIIAR – Scientific responsible: Prof. Fernando Sansò)

The PoliMi team intends to play a role of stimulus and scientific collaboration in almost all research lines, however paying a deeper attention both to the problem of optimal estimate of the potential coefficients in the framework of a space-wise approach and to the study of the iterative procedure between space-wise and time-wise approach.
More specifically, the team intends to:

- develop calibration routines exploiting the orbital cross-overs and study the possibility of estimating calibration parameters for long-time effects;
- develop and integrate all the software routines necessary for the space-wise analysis of the data, extending the present software to the treatment of other functionals, besides the second radial derivative;
- develop optimal integration methods of GOCE data with other global models of the field, included those derived from satellite observations only and those derived from ground data;
- collaborate to the establishment of the iterative space-wise / time-wise line;
- collaborate to the geophysical interpretations (both solid-earth and oceanography).

Research team UniPi
(University of Pisa – Dept. of Mathematics – Scientific responsible: Prof. Andrea Milani)

GOCE data processing with the time-wise method; digital calibration.

The Pisa research team will exploit its long-time experience in the field of time-wise data treatment (i.e. data organised along orbital arcs, causally connected) to work both on the simulation of the experiment and on the real treatment of the GOCE data with this method. However it must be kept in mind that the time-wise procedure represents only one step in an iterative procedure, including also the space-wise method. Since the systematic errors of the instruments (particularly, the gradiometer) are organised in a time-like (and not space-like) mode, it appears that the time-wise treatment will have the larger responsibility of the on-the-fly calibration. The removal of residual space-wise signals will have to be mostly under the responsibility of the space-wise approach.
The computational complexity of an end-to-end time-wise data reduction chain for the entire mission gives rise to non trivial problems. The development of algorithms for the decomposition of the problem is essential, particularly to avoid unsolvable storage problems.
We think it will be possible to adapt the methods already developed for the study of the SAGE mission, which in principle can be applied, but need a considerable software expansion.

Research team UniBo
(University of Bologna – Dept. of Physics – Scientific responsible: Prof. Nadia Pinardi)

Since October 1992 several satellites have been uninterruptedly providing data on sea surface height. Among them we recall ERS-1 and ERS-2 which, by means of an altimeter accommodated on-board, have been producing data deemed crucial in the study of climatic variability of the sea surface, hence of the sea surface circulation. To the aim of obtaining information on the ocean dynamics by using altimetric observations, it is necessary to know the sea surface height with respect to the geoid. Of course this task requires that the geoid is known independently of the information on the sea surface.
The only way to obtain an independent measure of the geoid with an accuracy of a few centimeters over spatial scales of the order of some hundred kilometers is represented by a dedicated gravimetric mission like GOCE. Lacking this opportunity, satellite altimetry would only continue to provide information on the temporal variability of the ocean dynamics, but not on the circulation averaged over time.
The group of physical oceanography and modelling of the University of Bologna co-ordinated by Prof. Pinardi has as its fundamental goal the study of the global oceanic circulation by means of the numerical modelling of the ocean physical system. The activities of the group started in 1986, focussing on the Mediterranean Sea modelling. Since then, the group has implemented both different models for the numerical simulation of the general circulation of the Mediterranean sea and of the global Ocean, and techniques for the assimilation of in-situ and altimetric data.
The use of these general models of circulation forced by the winds, heath and water fluxes, allow to estimate the mean circulation (i.e. averaged over time) both in the case of the Mediterranean and of the global ocean.

Besides, UniBo with the contribution of PoliMi will undertake the task of defining and producing a reference altimetric data set (DAR) to be used in the estimation of the mean oceanic circulation and of its variability. In particular, DAR will include the sea surface height anomalies and the related time averaged values processed and supplied by ESA. Finally, the reference data set will be combined with the geoid data produced by GOCE, and a final data set (DSF) will be produced containing the absolute topography of the sea surface. The DSF will be used for a comparison with the numerical simulations and will be included in the oceanic model, in order to build an optimal estimate both of the mean and fluctuating circulation.

Research team UniMi
(University of Milano – Dept. of Earth Sciences – Scientific responsible: Prof. Roberto Sabadini)

The usage of the GOCE data within Solid Earth Geophysics is related to two important research fields, the first one dealing with the outermost portion of the planet, namely the lithosphere and the upper mantle. GOCE will in fact provide a set of gradiometric data that will allow to improve the image of the outermost part of the planet with respect to what released today by seismic tomography alone. GOCE will thus provide information on the intensity of the density anomalies and on their geometries that can be used as constraints for geodynamic models that simulate the time evolution of lithospheric and mantle processes.

Simultaneous inversion of gradiometric and tomographic data.
Seismic tomography has allowed to gain, in the last decade, a global image of the seismic velocity anomalies in the mantle. These images provided important constraints on the global dynamics of the Earth mantle, in particular they have allowed to constrain subduction models of the oceanic lithosphere entering the mantle, based on density contrasts inferred from seismic tomography. These models reproduce the static component of the long wavelength geoid anomalies. On the other hand, seismic tomography alone is not capable to provide a detailed image of the density contrasts at the level of the lithosphere and upper mantle, because of the lack of uniform coverage over the Earth (lack of earthquakes and seismic stations) and of resolution in the density contrasts and geometries of tectonic structures. As fas as the density structure of the lithosphere and upper mantle is concerned, the tomographic images are not sufficiently well resolved to allow to build dynamic models that simulate the important geophysical processes that shape the surface of the Earth or induce important phenomena that interfere with the life of the human beings, namely the secular components of sea level changes and the earthquakes.

Forward models of geodynamical processes.
The target of this research line covers one of the most important aspects of solid earth geophysics, namely the implementation of mathematical models of the Earth that simulate the most important geophysical processes, with the aim of understanding the physical mechanisms that underly the evolution of our planet, and of providing us with tools to make predictions on the time evolution of the geophysical processes themselves. The last issue is clearly of importance in order to understand how the environment will evolve in time, from the point of view of Solid Earth Geophysics (secular components of sea level variations, seismicity, crustal deformation).

Research team UniTn
(University of Trento – Scientific responsible: Prof. Battista Benciolini)

The team intends to study the problem of gradiometric data interpolation in the framework of the space-wise approach to the modelling of the field. Interpolation is necessary to obtain data on a regular grid, distributed on a simple surface in order to be able to apply fast algorithms (e.g. FFT) and algorithms derived from the boundary value problem theory.
To this aim, various methods for local data modelling must be theoretically studied and subsequently tested on simulated data: in particular, one can consider the use of finite elements interpolators, wavelets and collocation.

Research team UniPd
(University of Padova – Scientific responsible: Prof. Stefano Casotto)

The scientific contribution of the CISAS/UPD research team will concern the 1) modelling of the force field affecting the orbit of the GOCE satellite and 2) modelling of the measurement links between the LEO satellite and the GPS and GLONASS space vehicles in order to produce highly accurate ephemerides of the GOCE satellite. These ephemerides will be used for 3) the retrieval of the low frequency part of the Earth gravitational field and will also benefit the reduction of the gradiometric measurements for the high frequency part.

On the basis of previous work performed by the CISAS team in the field of GPS- and GLONASS-Based Precise Orbit Determination (POD), the main tool to be used to accomplish the goals stated above will be an Orbit Determination and Geodetic/Geophysical Parameter Estimation Program. The CISAS team has already developed a functioning version of such a tool. It will be necessary for the present application to review the available software and optimize its architecture in order to take advantage of faster processing algorithms based on heavy use of core memory to bypass current limitations set by mass memory I/O operations.
The force models to be implemented will also need to be reviewed, in particular the non-gravitational force modelling through the common-mode gradiometer readout. Interaction with the end-to-end simulator developed by Alenia will be a primary means of operation for the simulation studies of orbit and LF gravity field recovery.

INTERNATIONAL CO-ORDINATION OF GOCE - ITALY

As it is obvious all the effort provided by GOCE - Italy has to be seen within the framework of a strict international co-operation structured in the form of the EGG-C Consortium. In particular, the idea is that the role of interface could be played by the Politecnico of Milano group, that could fully participate in the EGG-C works, where the Italian results will be reported. As a corollary also the new scientific needs arising in the international context and for which GOCE - Italy is qualified will duly be taken into account even modifying when necessary our present plans.

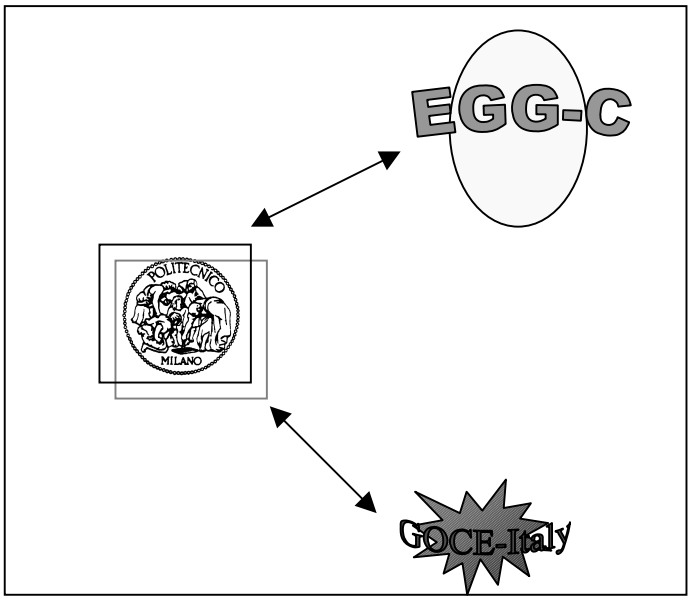

Fig. 2. GOCE – Italy co-operates with EGG-C through Politecnico di Milano

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