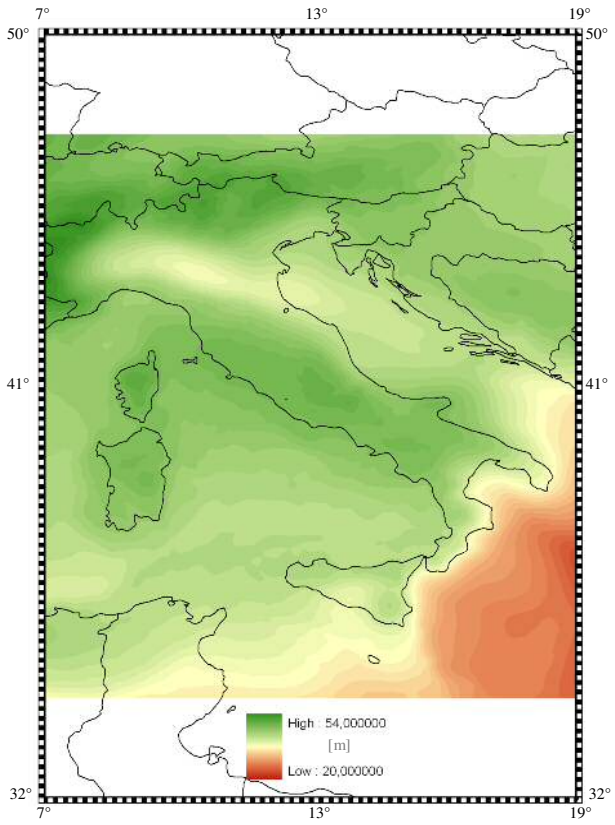

ITALIAN GEODETIC RESEARCH ACTIVITIES IN THE PERIOD 2011-2013

IAG REPORT

BY F. SANSÒ
ITALIAN DELEGATE TO IAG

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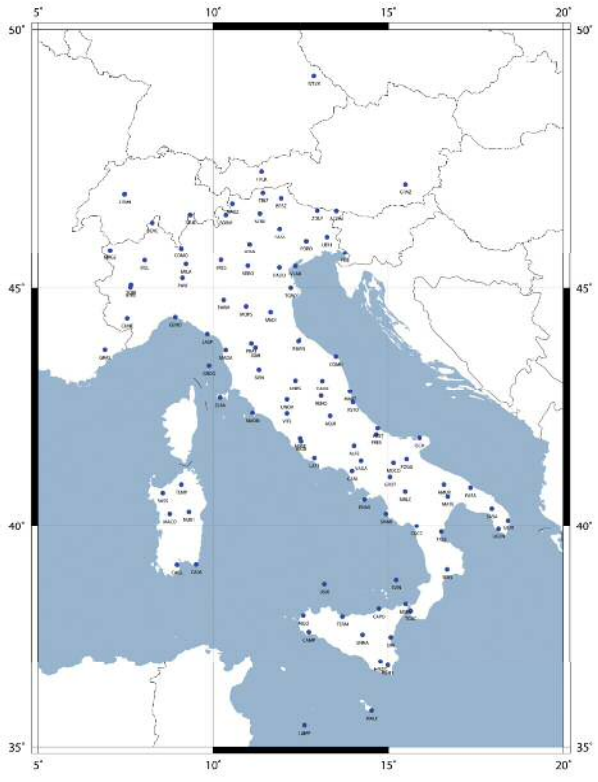

International Association of Geodesy (IAG) by Fernando Sansò

Activities in Italy (2011-2013)

Short summary
The report is organized by 4 IAG_Commissions, the Inter-Commission Committee on Theory and the Services.
For each of them we report: name, contact persons, participants to structures, scientific reports, bibliography.

Note: the geodetic Community is organizing a IAG-Italy website (http://w3.dicea.uniroma1.it/iag-i/) which is starting now its activity and will hopefully monitor the relevant projects in real time.

Structures:

Commission 1 (Reference Frames)

Contact persons
A. Caporali
G. Bianco
R. Maseroli
L. Biagi

Participants to IAG Structures

JWG 1.1 on ties of Space Observations
P.Sarti (Chair)
C. Abbondanaza
G. Bianco
L. Vittuari

WG 1.4.2 on celestial reference frames
V. Tornatore

Italian Institutions
ASI
IGM
CNR
Universities (PoliMi, PoliTo, UniBo, UniRoma, UniPg, UniPd)

Summary
Activities related to the establishment and maintenance of the Terrestrial Reference Frame, from both the instrumental and the theoretical point of view.
Particularly relevant is the participation of ASI to the various IAG Services. Also the theoretical discussion on the relation and simultaneous modelling of deformations of the Earth surface and of the variation of the Earth orientation parameters in a terrestrial system is relevant.
The implementation of a national reference system into the ITRS has been object of intensive work and Projects of National Interest.

Scientific Reports

Activities of A. Caporali in Geodetic Projects, 2011-2013

1) As Chairman of the CEGRN Consortium (Central European Geodynamics Research Network): Geokinematic investigations in Central Europe using long term data (1994-2011) from epoch and permanent GNSS stations.

2) As Secretary of EUREF IAG Reference Frame Sub-Commission for Europe, integrated in the Sub-Commission 1.3, Regional Reference Frames, under Commission 1 – Reference Frames: Maintenance of the European Reference System and its realizations. Processing standards for GNSS data. Relation to IGS, EuroGeographics and National Mapping and Cartographic Authorities in Europe.

3) As member of the Thematic Working Group 1 (Coordinate Reference Systems) and 2 (2D and 3D geographic grids) of the INSPIRE EU Directive/Annex 1: preparation of the Implementing Rules.

4) As member of the Processing Group of the Rete Dinamica Nazionale (RDN) of IGMI (Istituto Geografico Militare Italiano): maintenance of the RDN at regular intervals.

5) As responsible of the GPS network of the Regione Veneto: maintenance of the 26 GNSS permanent network, alignment to RDN/ETRS89, weekly network adjustment with Bernese 5.0 and IGS/EPN processing standards, analysis of Time Series

6) As member of the NSPR Project (Network of Permanent GPS stations): weekly computation and adjustment of the network of 400+ GNSS stations in Italy, representing a densification of the RDN. Weekly SINEX files are sent to EUREF for combination and stacking with the EPN normal equations, for densification of the ITRF2008 in Europe.

7) Support to IAG SC1.3 - WG1 Integration of dense velocity fields into the ITRF by sending SINEX files of the Italian network to EUREF for combination and stacking with the EPN normal equations, for densification of the ITRF in Europe.

8) Geophysical modelling of the inferred velocities, correlation of the areas of high strain with structural geology, historical seismicity.

Activities of R. Maseroli in Geodetic Projects, 2011-2013

1) Revision and new determination of the Italian Dynamic Network (RDN), finalized to the possible estimation of the crustal movements, and to the updating of the coordinates.

2) Computation of the geopotential, the dynamic heights and the normal heights of all data of the Italian high precision levelling lines (about 20000 benchmarks), through measures of gravity estimated on the basis of the model ITALGEO2005 italian geoid.

3) New determination of some Italian high precision levelling lines (about 1000 km) and updating of the heights.

4) densification of the points GPS + levelling (about 100 points), for the future improvement of the Italian model of geoid.

5) Realization of a certified national net NRTK, for the dissemination of the real time GNSS

corrections.

Activities of L. Biagi in Geodetic Projects, 2011-2013

Politecnico di Milano has lead a project, funded by Italian Ministry of University, named
"The new Italian geodetic reference frame: continuous monitoring and use in environment management". The project started in 2008 and ended in 2012. As a matter of fact, the Italian reference frame (denominated national dynamic network, in Italian Rete Dinamica Nazionale, RDN) had been established in 2008, by using one month of data (last two weeks of 2007, first two weeks of 2008) of 100 national permanent GPS stations and presented and approved by the EUREF structure as complying with international standards: in 2008 the RDN solution was officially published in the website of Istituto Geografico Militare. This was accomplished by IGM Institute in cooperation with Politecnico di Milano and other centres.
In the following years, the problem arose of establishing a proper methodology and praxis to manage and monitor the national reference frame. Meanwhile permanent GNSS networks have been developed at different scales and for different purposes. Therefore, the funded project aimed at:
1) reconducting all this activity to a unitary point of view under the theoretical and practical concept of geodetic reference frame,
2) establishing the national reference frame (NDN) on the basis of a continuous time ("monitoring") solution leading in this way the Italian community to a level finally compatible with the international reality of developed countries,
3) providing a number of documents of the type "certificate", to be used by regional authorities in particular for the economically sensitive item of RTK positioning services,
4) providing the first answers to a strategic question, namely whether , how and, in case, when a homogenized structure for positioning services at national level has to be created.

In particular, the following researches have been completed in the years 2011-2012.
1. Analysis of the status of RDN, definition of a protocol for those permanent stations that would be accepted in the network and creation of a data base for the project.
2. Computation of the solutions of RDN over the time span between 2008 to 2012, with different SW of international relevance.
3. Implementation of a rational experiment to prove or disprove the feasibility of an RTK positioning service at national level.
4. Analysis and solution of the problem of framing a sub-network into a larger network, overcoming some incorrect current practices.
5. Investigation of the problem of time series prediction of the coordinates of individual stations, assessing a specific stochastic prediction model for each of them.
6. Set up of an optimal predictor of the deformation pattern accounting for the spatial correlation structure of the network.

Activities of G. Bianco in Geodetic Projects, 2011-2013

The ASI Space Geodesy Center "G. Colombo" (CGS) has contributed to the IERS Technique Centers (ILRS, IVS, IGS/EUREF) since the beginning of the Service activities both as fundamental station and analysis center.
The ILRS Governing Board recognized ASI/CGS' continuous and rigorous contribution and appointed it as one of the official ILRS Analysis Centers (ACs) when the ILRS AC structure was finalized (2004). In June 2004 the CGS was selected by the International Laser Ranging Service (ILRS) as its primary Official Combination Center (CC) for station coordinates and Earth Orientation Parameters.
ASI/CGS is an official IVS Station, Data Center and Associate Analysis Center since the beginning

of the service (1999).
ASI/CGS is operating as EUREF Local Analysis Center (LAC) since 1996, producing since then the requested solutions for the European reference frame densification and tropospheric applications. More recently (2009), ASI-CGS became also an European Permanent Network (EPN) Regional Broadcaster for the dissemination of Real Time orbit and clock corrections as well as observation streams. Since 2012 ASI/CGS is contributing to the EUREF Technical Working Group.
In January 2012 a GNSS receiver has been installed at the CGS in the framework of the IGS Multi-GNSS (M-GEX) experiment.
ASI/CGS has been participating since 1999 to many GPS Meteorological projects (COST 716, MAGIC, TOUGH, E-GVAP) and is presently participating to E-GVAP III (2009-2013, contribution to the operational meteorology) as Analysis Center and Combination Center and is now involved in the COST Action ES1206.
In January 2010 ASI/CGS has been appointed as GGOS Coordination Office.
Information on the CGS and some of the analysis results are available at the CGS WWW server GeoDAF (Geodetic Data Archiving Facility, http://geodaf.mt.asi.it).

SLR Data Analysis

ILRS Activities

In the years 2011-2013, the ASI/CGS has been involved in the ILRS activities, mainly in support of the reference frame maintenance and under the coordination of the Analysis Working Group. Due to its double role of Analysis Center and Combination Center, ASI/CGS provides both its single AC solution and the combined product of the 8 ILRS ACs, whenever requested. Main projects are:

- **Official ILRS Products**: Weekly and Daily site position and Earth Orientation Parameters obtained using LAGEOS and ETALON data. The solutions provide the weekly coordinates of the worldwide SLR tracking network and the daily EOPs as the ILRS contribution to the USNO Rapid Service.
- **ITRF maintenance**: long term time series of site coordinates and EOPs computed according to the requirements of the IERS inter-technique Combination Centers
- **IERS Pilot Project** to evaluate the impact of non-tidal atmospheric loading at the observation level.
- **Pilot Project on Weekly orbits:** satellite ephemerides for Lageos and Etalon, preliminary periodic evaluation/comparison of the ACs weekly orbits in order to produce a combined official product.
- **Station qualification:** ASI/CGS is one of the ACs designated by the AWG to validate the data from new or upgraded sites or after an earthquake.
- **Bias monitoring:** routine activity carried out to compute data corrections whenever the biases are not reported by the station, in close contact with the station engineers.

IERS contribution: production of EOP time series regularly carried out as ASI/CGS operational EOP series:

ETRUSCO-2 Project: characterization and validation of the optical performance of satellite Laser Ranging Arrays under laboratory-simulated space conditions.

ASI/CGS internal projects:

The ASI/CGS SLR analysis activities extend beyond the accomplishment of its role within ILRS/IERS and were addressed in the following main application fields:

- **Reference Frames:** annual generation of multi-year solutions from Lageos I and II data, used as a benchmark for global network coordinates/velocities EOPs, satellite ephemerides and accelerations, station biases
- **Gravity**: long term time series of low degree Earth's geopotential coefficients and geocenter.

VLBI Data Analysis

IVS Activities

In the years 2011-2013, the ASI/CGS has been involved in the following IVS projects:

- **Session Earth Orientation Parameter Series:** Time series of X pole, Y pole, UT1, Xp rate, Yp rate, UT1 rate, dpsi, and deps.
- **Terrestrial Reference System (TRF):** Set of station positions, velocities, and correlations
- **Celestial Reference System (CRF)** Set of right ascension and declination for sources
- **Tropospheric Parameters:** Regular submission of tropospheric parameters for all VLBI stations observing in the IVS R1 and R4 sessions the results are available on the IVS products ftp sites.
- **Daily Solution Files** Pre-operational submission for each 24-hour session to provide earth orientation and site positions, the covariance matrix of the estimates and decomposed normal equations.

IERS Contribution Regular submission to the IERS EOP operational series of R1 and R4 session EOP estimates

ASI/CGS internal projects:

- **Global VLBI Solutions:** Every year, global VLBI solutions are produced, including all the observation sessions since 1979 onwards. The estimated parameters of the global solution are:
  - Celestial Frame: right ascension and declination as global parameters for 637 sources
  - Terrestrial Frame: Coordinates and velocities for 92 stations as global parameters
  - Earth Orientation: Unconstrained X pole, Y pole, UT1, Xp rate, Yp rate, UT1 rate, dpsi, and deps.

GPS Data Analysis

EUREF/IGS Activities

In the years 2011-2013, the ASI/CGS has been involved in the EUREF activities, mainly in support of the reference frame maintenance. Main projects:

- **Official EUREF Products**:
  EPN Final weekly product: site coordinates and tropospheric parameters using IGS Final products, now covering a European sub network of 41 sites, 2-week latency
  EPN Rapid daily product: site coordinates using IGS Rapid products, now covering a European sub network of 41 sites, 1-day latency
  EPN NRT hourly product: site coordinates using IGS Ultra-Rapid products, now covering a European subnetwork of 41 sites, 1-hour latency
- **EPN Real Time Analysis:** ASI-CGS is an EPN Regional supporting the dissemination of RT orbit and clock corrections and observation streams. It contributes directly to the data stream with 3 RT GNSS stations.
- **EPN Reprocessing:** Reprocessing the EPN Network from 1996 onwards.

IERS contribution: Pre-operational submission to the IERS EOP operational series of GPS daily EOP estimates

GNSS Meteorology Activities

In the years 2011-2013, the ASI/CGS has been involved in the GNSS-Met activities as E-GVAP Analysis Center and Combination Center.

- **Official E-GVAP Products**:
  NRT ZTD estimates: every hour, 15m ZTD estimates with a 1h45m latency for an European network of more than 200 sites are produced;
  NRT ZTD combined estimates: every hour, the 15m ZTD estimates from the contributing E-GVAP Analysis Centers are combined and made available to the project, using a

combination SW developed at ASI-CGS.

Quality Control: on hourly basis AC bias w.r.t. the combined solutions are computed providing a quality indicator for each solution.

ASI/CGS GNSS-Met activities in support of NWP applications, nowcasting and forecasting of severe weather events will continue, in the following years, within the framework of E-GVAP phase III and of the EU COST Action "Advanced Global Navigation Satellite Systems tropospheric products for monitoring Severe Weather Events and Climate" (GNSS4SWEC).

ASI/CGS internal projects:

The ASI/CGS GPS analysis activities extend beyond the accomplishment of its role within EUREF and E-GVAP and were addressed in the following main application fields.

- **Reference Frames:** annual generation of multi-year solutions of site coordinate and velocity of a GNSS network covering the central Mediterranean area.
- **Zenith Tropospheric Delays (ZTD) Residual Fields:** hourly generation of ZTD residuals fields covering the central Mediterranean area.

Multi-technique Data Analysis

COL Working Group: submission of requested weeks (CONT-08 and -11 campaigns) for SLR solutions in the form of NEQ SINEX and participation to the WG activity.

ASI/CGS internal projects:

- **Gravity**: long term time series of degree 2 Earth's geopotential coefficients variations obtained from SLR and VLBI EOP estimates, through excitation functions and time/frequency comparison with Angular Atmospheric and Oceanic Momenta components (from IERS dedicated sub-bureaus).
- **EOP excitation functions** Regular production of the daily geodetic excitation functions from the ASI/CGS estimated EOP values for IERS (SLR, VLBI), since 2006.
- **Geodetic solution combination** Realization, implementation and testing of combination algorithms for the optimal merging of global inter- and intra-technique solutions and of regional (e.g. Mediterranean) solutions to densify tectonic information in crucial areas.

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Commission 2 (Gravity Field)

Contact persons R. Barzaghi
M. Reguzzoni
I. Marson
C. Braitenberg

Participants to IAG Structures

SC 2.3 Dedicated Satellite Gravity Missions
F. Migliaccio

SC 2.4f Gravity and Geoid in Antartica
A.Capra

SC 2.6 Gravity and Mass Displacements
C. Braitenberg

JWG 2.1 Techniques and metrology for absolute gravity
A.Germak
F. Coren

JWG 2.2 Absolute gravity
D. Iacorone
A. Germak

JWG 2.3 Assessment of GOCE models
R. Barzaghi

JWG 2.4 Interpretation of Tibet, Xinjiang and Siberia
C. Braitenberg

JWG 2.8 Inversion of gravity with solid Earth coupling
C. Braitenberg

Italian Institutions

OGS
INGV
CNR
Universities (PoliMi, UniTs, UniTn)

Summary
A lot of work has been done in conjunction with ESA structures and NGA and the item of global and local modelling of the gravity field, in particular to estimate local geoids including the new data sets coming from the Goce mission. Also the GOCE Italy project has been developed, with several geophysical and geological and oceanography applications.

Scientific Reports

Activities of R. Barzaghi and M.Reguzzoni in Geodetic Projects 2011-2013

- **Gravity field estimation using satellite and ground based data**

Ground based gravity data have been combined with satellite data to get an improved estimate of any functional of the anomalous potential T. GOCE T_{zz} observations available at ESA have been combined with radaraltimetry and gravity anomalies at ground level using collocation. In performing the collocation estimate an improved covariance fitting procedure has been devised and applied. In this way an integrated estimate of the geoid has been obtained and tested versus available GPS/leveling data. The performed tests in the Central Mediterranean area have provided reliable estimates.

- **Deflection of the vertical estimation**

Deflection of the vertical estimation has been performed based on gravity data. This allowed a proper reduction of observed zenith and azimuth angles measured in a precision traverse for estimating reference point coordinates in the Gran Sasso Laboratories. These reference points on the Borexino, Icarus and LVD experiments have been used in the context of international experiments aiming at re-estimating the neutrino velocity based on neutrino beams from CERN.

- Height datum problem

The global height datum problem, that is the determination of biases of different height systems at global scale, has been revised and one solution has been proposed. In this approach height anomalies derived from GNSS ellipsoidal heights and biased normal heights have been compared with height anomalies derived from an anomalous potential which combines a satellite-only model up to degree 200 and a high-resolution global model above 200. Numerical tests have been devised to prove the effectiveness of this method and an error budget has been performed. Also, at local level, GOCE data has been used to unify the Italian and Swiss geoids in the framework of the HELIDEM project. Further studies are ongoing

- **Satellite geodesy**

Analyses on satellite gravity missions have been performed with particular attention to the data analysis of the GOCE mission for gravity global and local model estimation and for geophysical applications.

- **Aerogravimetry**

This research aims at local gravity field modelling taking advantage of GOCE data for the low frequency part of the field and improving the acceleration estimation by the nowadays available GNSS constellations.

- **Crustal deformation laboratories**

The network of stations with underground deformation measurements in North-eastern Italy is maintained. The three stations house tiltmeters and extensometers, including the famous Grotta Gigante „Long-base Pendulums“ in the Trieste Carst. This station has an exceptionally long continuous data series of near to 50 years. The research includes free oscillations of modern mega-earthquakes compared to the historic Chile 1960 event. Further the underground hydrology is studied through the induced tilt signals.

- GOCE observations for the detection of natural resources.

GOCE has revolutionized the knowledge of the gravity potential field in remote areas. The studies include sensitivity analysis of GOCE for geologic structures relevant for oil and mineral exploration. Methodological aspects are studied to define the best way to extract the geological

signal from the GOCE observations using either the on-track gradient observations or the derived global gravity models. Software has been developed, including the modelling of tesseroids and for the inversion of the crustal density inhomogeneities. The methods have been applied to Africa, South America and Alps, demonstrating the huge leap ahead that GOCE has delivered for the use of potential methods in exploration in remote areas.

- **Funded projects**

In the following, the main funded projects related to gravity researches are briefly described:

GOCE-HPF (High-level Processing Facilities): funded by the European Space Agency (ESA), it involves European university and research centers with the final aim of producing Level 2 GOCE data and estimating a global model of the Earth gravitational field. Politecnico di Milano is responsible for the model by the space-wise approach and it is now computing global grids of gravity gradients at mean satellite altitude that should have a higher local content than the one of the spherical harmonic coefficients.

GEMMA (GOCE Exploitation for Moho Modeling and Applications): co-funded by ESA-STSE and ASI, the main goal of the project was to map the crust-mantle discontinuity (Moho) all over the world and in key regions by means of GOCE data. The obtained Moho is also based on ETOPO1 and a 1°x1° sediment model for the shallowest layers. The crust is divided into geological provinces, each of them characterized by its own relation between density and depth. The GEMMA Moho is freely available and delivered with the support of a Web Processing Service (WPS).

GAL (Galileo for gravity): funded by the European Community, it is a project of aero-gravimetry based on the joint used of positioning techniques, such as GPS, EGNOS and in particular Galileo systems, inertial measurement units (IMUs) and satellite gravity data and global models derived by the GOCE mission for the estimation of low frequency part of the gravity field; the proposed solution does not make use of on board gravimeters.

VIKING (Very Improved KINematic Gravimetry): funded by ENI, it is a project with the aim of improving performances of airborne kinematic gravimetry in terms of accuracy and spatial resolution of the retrieved local gravity field; this is done by fully exploiting the current state of the art satellite technology (GNSS multi-constellations), IMUs, on board gravimeters and innovative processing strategies.

DPC 2012-2013: in the framework of the seismological projects of INGV, activities have been performed to enhance the Italian ground gravity database with the low frequency information coming from the GOCE mission; this has been done for the Po Plain area. The final aim of these activities was to investigate the crustal velocity and density 3D modelling in the Po Plain, with the support of GOCE satellite gravity data too.

Activities of C.Braitenberg in Geodetic Project 2011-2013

1) Crustal deformation laboratories

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Commission 3 (Earth Rotation and Geodynamics)

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Participants to IAG Structures

SC 3.5 Tectonics and Earthquake Geodesy
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JSG 3.1 Gravity and height change intercomparaison
S. Zerbini

Italian Institutions

ASI
CNR
INGV
OGS
Universities (PoliMi, UniBo, UniMi, UniMo, UniRoma)

Summary

Most of the activity in the framework of Commission 3 is related to geodynamics and deformation analysis. Particular attention has been devoted to the combination of different techniques in the analysis of post seismic deformation.

Scientific reports

Activities of S.Zerbini in Geodetic Projects 2011-2013

Application of space techniques to geodesy and geodynamics. Study of regional and local deformations of the Earth's crust, in particular, monitoring, interpreting and modelling short- and long-term vertical motions by means of the Global Positioning System (GPS), other space techniques and by high precision terrestrial gravimetry. Study of sea-level fluctuations in relation to climate variability and change. Study, by Principal Components Analysis, of temporal and spatial variability of GPS station positions and of key hydrological variables. Integration of techniques, GPS and InSAR in particular, including study of wet tropospheric path delay.

1) Member and past chair of the "Tectonics and Earthquake Geodesy (WEGENER)" Steering Committee. WEGENER is sub-commission 3.5 of IAG Commission 3.

2) Member of the Working Group for the internationalization of Research of the Italian Ministry of Education, University and Research.

3) Chair of the EGU Vening Meinesz Medal Committee.

4) Member of the Executive Committee of GGOS.

5) Member of the Science & Technology Committee of GEO representing IAG.

6) Member of the Editorial Board of the Journal of Geodynamics.

7) Member of the GEO Supersites SAC, representing WEGENER.

Activities of R.Devoti in Geodetic Projects 2011-2013

Tectonic geodesy and geodynamics
INGV is hosting a nationwide GPS network (RING) dedicated specifically to the monitoring of current crustal deformation in Italy. The data are daily transferred to the central archive in Grottaminarda (ring.gm.ingv.it). Different analysis groups at INGV process routinely the GPS data of the RING network and other permanent networks in the Italian region, currently producing solutions of over 600 sites every day using basically three different approaches: Gamit, Bernese, Gipsy. The time series are the fundamental products that allow researchers to study the kinematics of the region, to discriminate the plate boundaries and to recognize the active deforming regions. These studies suggest important clues and significant advances in seismic hazard investigations and current tectonic mechanisms.

Geodetic observations at fault scale or regional scale
To study the seismic cycle at the fault level, it is useful to observe the co-, post- and inter-seismic deformations in limited areas across the active faults. Typical observations include GPS and leveling data, classical terrestrial methods. Alternatively, in small regions interested by volcanic activity the geodetic monitoring is crucial for source analysis and danger warning. INGV is managing numerous campaign networks or small permanent networks dedicated to local tectonic and/or volcanic active processes. These applications often require a real time analysis and real time alert response.

InSAR ground deformations and comparison with GPS
Interferometric SAR measurements are currently processed at INGV and interpreted to study the coseismic and interseismic deformations occurring in different places on the Earth surface. The integration and comparison of InSAR and GPS results may enhance the picture of the ongoing deformation by exploiting the strengths of both techniques, high spatial resolution and high time resolution respectively.

Combination of geodetic solutions at the normal equation level
Geodetic solutions (coordinates and/or velocities) are usually obtained from different processing methods or different observation techniques. The combination of such solutions at the normal equation level allow to integrate all the solutions rigorously in a unique reference frame. This procedure is fundamental in terrestrial reference frame construction, geodetic validation processes and buildup of large network velocity solutions.

High rate GPS observations for seismic events
The capability of high rate GNSS observations allow to study the direct ground shaking during an Earthquake. At INGV a number of studies have been carried out since the L'Aquila earthquake in 2009 and consequently the RING network has been configured such as to enable the archiving of high rate observations in case of seismic events on the Italian territory.

Activities of **A.Capra** in Geodetic Projects 2011-2013

The geodetic activity performed was principally devoted to Antarctic geodetic surveying for geodynamics purposes. Within this research Capra is the Responsible of two projects:

1) Geodetic Observatory in Northern Victoria Land
2) Geodetic Observations for northern Victoria Land monitoring

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Commission 4 (Positioning and Applications)

Participants None

Italian Institutions

IGM
CNR
Universities (all Engineering Schools)

Summary
The activities for the framework of Commission 4 are various and range from the study of GPS applications to real time positioning, to navigation, to the use of SAR for ground movements monitoring. A particular mention has to be done for the application of a stand alone GPS to reconstract seismic waveform. Also the development of a free ware navigational software (GoGPS) which is developed under an international cooperation.

Scientific Reports

Activities of A.Manzino in Geodetic Projects 2011-2013

Local responsible of the Politecnico di Torino for the PRIN 2008 project with a title " The new Italian geodetic reference system: continuous monitoring and applications to the management and control of the territory."

Local responsible of the Politecnico di Torino for the Italy-Switzerland Interreg project HELI-DEM (HELvetia – Italy Digital Elevation Model) related to the unification of the reference systems and the creation of a single digital model of heights.

Responsible for GNSS NRTK network managed by Politecnico di Torino and coordinator of the project for the creation of new GNSS Regione Piemonte network for RTK positioning.

Local coordinator of the project "Quality Control of GNSS positioning within NRTK networks".

Activities of S.Gandolfi in Geodetic Projects 2011-2013

PNRA – Research program for Antarctic Research
(Operative Unit Geodesy): Studies on Geodynamic and Post Glacial Rebound (PGR) of the Victoria Land (Antarctica). These studies are carried out by means of space geodetic techniques and in particular using GNSS. In order to perform correct results interpretation, several methods, approaches and data processing software packages have been used.

(Operative Unit Glaciology): In this contest the geodetic activities are regarding two main aspects. First of all studies on surface deformation of the plateau, by means of GNSS technologies) in correspondence of two deep drilling sites useful for the dynamic of the two areas. The second aspects regard all the geodetic activities required for the localization of geophysics survey such as GPR. In particular in this field a lot of studies have been carried out in the Precise Point Positioning field for static and kinematic surveys.

GNSS Precise Point Positioning
The research is oriented to the definition of the best models and methods, including the framing aspects using regional reference network, for high accurate positioning. This research try to focus also the impact of the windows time observation to the final accuracy. All these tests have been carried out using GIPSY OASIS II.

PRIN 2010.
In the field of National Program PRIN2010 the geodetic activities are relating to the possibility to realize a prototype of autonomous GNSS permanent station. This prototype constitute the first step for the establish a CORS (Continuously Operating Reference Stations) for Emergency.

Activities of M.Crespi in Geodetic Projects 2011-2013

Main research topics
GPS Seismology: VADASE
GPS Meteorology: inter-comparison of water vapor estimation approaches
Digital Surface Models generation from high resolution optical and SAR satellite imagery

GPS Seismology: VADASE
VADASE (Variometric Approach for Displacements Analysis Stand-alone Engine) is a new approach to estimate coseismic displacements in a global reference frame in real-time based on a single GPS station technique and on standard GPS broadcast products (orbits and clocks). Since it does not require either additional technological complexity or a centralized data analysis, in principle it can be embedded into the GPS receiver firmware, thereby providing a significant contribution to tsunami warning systems.
The effectiveness of VADASE was tested on several earthquakes, including the last extremely strong one occurred in Japan on March 11, 2011 (VADASE supplied the first worldwide solution for the displacements at two IGS site (MIZU, USUD) and, at first, was presented at IUGG 2011 General Assembly in Melbourne.
In the last two years it was extended to Galileo and Glonass, refined and thorough compared on real observations with four renown software, used as reference, following different approaches (APP-PPP and CSRS-PPP, Bernese and TRACK), with an agreement at 1-2 cm level, quite close to the agreement between the reference software.
It was also successfully tested using observations simulated by Spirent simulators, thanks two cooperations with DLR (German Aerospace Agency, Oberpfaffenhofen, Germany) and CATEC (Centro Avanzado de Tecnologías Aeroespaciales, Sevilla, Spain).
Moreover, thanks to a cooperation with Leica Geosystems AG (Heerbrugg, Switzerland), VADASE was implemented onboard a GR10 GNSS receiver and tested.
A new cooperation with NCKU (National Cheng Kung University, Taiwan) has been recently started for a possible application of VADASE to the real-time GNSS network managed by the Department of Earth Science.

GPS Meteorology: inter-comparison of water vapor estimation approaches
The research was developed within an international cooperation with the Universidad Nacional de La Plata (La Plata, Argentina) and the Universidad Nacional de Cuyo (Mendoza, Argentina), partially funded by the Italian Foreign Ministry and the Argentinean Science and Technology Ministry. The goal was the inter-comparison of different approaches to estimate the atmospheric water vapor (WV) both over land and over sea: ground-based approach using GNSS observations, satellite-based approach using radiometer observations acquired in the Jason-1 mission, and model-based using the ECMWF meteorological model.
The comparison was at first focused on GNSS-Jason-1 WV estimations comparison along the South America coastline (where both the techniques may supply results), considering some GNSS sites

included in SIRGAS network, and the focus was both to point out the comparison problems and to assess the agreement level, depending latitude, time of the day and season of the year. A dedicated software was implemented in order to softly manage the extremely huge data-base coming from Jason-1.
Secondly, a comparison between SIRGAS and IGS WV estimations in the same GNSS site was developed, in order to point out possible significant inconsistencies; then, a comparison between SIRGAS and ECMWF model estimations in the GNSS site was started, with the aim to design an integration strategy to improve regularly WV estimations all over South America.

Digital Surface Models generation from high resolution optical and SAR satellite imagery
The research was developed within the international project *Evaluation of DEM derived from TerraSAR-X data* leaded by Prof. Uwe Soergel (Leibniz University Hannover, Germany) and supported by DLR, a second international project *Influence of sensor orientation method, number and distribution of ground control points, image acquisition incidence angles, and strip length on the horizontal accuracy of WV2 satellite orthoimages* leaded by Dr. P. Astrand (Joint Research Center European Commission, Ispra, Italy), an international cooperation with Dr. T. Toutin (Canada Center for Remote Sensing, Ottawa, Canada) and the national project *On the exploitation and validation of COSMO-SkyMed interferometric SAR data for digital terrain modelling and surface deformation analysis in extensive urban areas* leaded by R. Lanari and supported by ASI (Italia Space Agency).
A rigorous model to orientate optical and SAR imagery coming from different sensors and a tool for Rational Polynomial Coefficients generation (based on the rigorous model itself) were implemented in SISAR package, tested and successfully compared with other models.
Moreover, an original image matching strategy for Digital Surface Models (DSMs) generation from both optical and SAR imagery (in this case according to a radargrammetric approach) was implemented, tested and compared with other approaches.
A particular concern was devoted to radargrammetric DSMs generation from high resolution SAR imagery acquired by COSMOSkyMed, TerraSAR-X and RADARSAT-2, focusing the filtering for image enhancement and the comparison with interferometric generated DSMs in view of a future integration.

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Awards

2012 ESNC (European Satellite Navigation Competition) – VADASE included into the "Success Stories"

2012 Italian Association of Professors in Geomatics – Best Ph.D. Thesis (Ph.D. student: Gabriele Colosimo – Supervisor: Mattia Crespi) - topic: VADASE approach for GNSS displacement monitoring

2013 ESNC (European Satellite Navigation Competition) – VADASE testimonial of the 2013 competition as Success Story (http://www.galileo-masters.eu)

2011 Italian Association of Professors in Geomatics – Best Ph.D. Thesis (Ph.D. student: Francesca Pieralice – Supervisor: Mattia Crespi) - topic: imagery orientation models for radargrammetry with

high resolution SAR satellite sensors
2012 Google – Grant for Google Summer of Code – Ph.D. Student: Andrea Nascetti, Ph.D. Gabriele Colosimo - topic: orthophotos from high resolution SAR satellite imagery within open-source Optik software

Patent
2012 International patent for VADASE supported by the University of Rome “La Sapienza”
2013 Italian patent for matching strategy for optical and SAR high resolution satellite imagery supported by the University of Rome “La Sapienza”

Inter-Commission Committee on Theory (ICCT)

Contact persons F. Sansò
C. Braitenberg
F. Sacerdote

Summary

Two events are worth to be mentioned in this framework: the publication of an intensive theoretical book of physical geodesy by Springer; the organization of a new Hotine-Marussi Symposium on Geodetic Theory in Rome on June 2013.

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Global Geodetic Observing System - (GGOS)
Coordinating Office G. Bianco

Services

International Gravity Field Service - (IGFS)
R. Barzaghi (Chair)
I. Marson (Boureau)
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International Geoid Service – IGeS
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A. Borghi

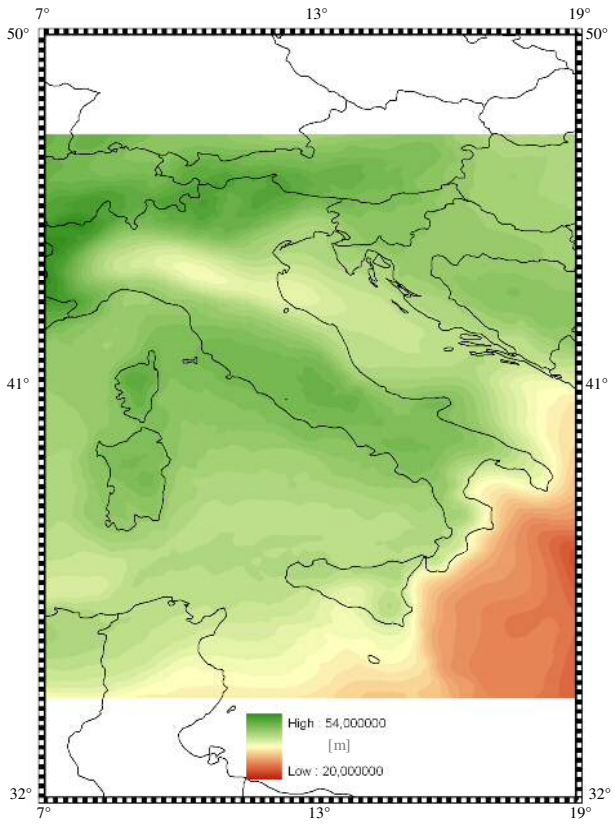
The main IGeS scientific activities in the period 2011-2013 have been related to two research areas: the methods for merging local geoid estimates; the analysis of the global height datum. Both problems are strictly related to the IGeS mission that is focussed on local/regional geoid estimation and evaluation. Theoretical solutions to the two problems have been devised and tested on numerical examples in order to prove their feasibility. Furthermore, the support activity on geoid computation continued. IGeS has co-operated with the Centre for Geodesy and Geodynamics of Nigeria in giving a training course on geoid estimation theory and geoid estimation software. IGeS also was supporting the computation of the geoid in the San Paolo state in Brazil. Finally, IGeS web site was totally renewed and the local geoid solution database was improved by adding new local solutions (namely the Switzerland geoid, the French geoid, the new European EGG2008 geoid and the US geoid). Geoid Schools were also planned and organized. The next one will be held in October 7th-11th, 2013 at the Universidad Tecnica Particular de Loja in Loja, Ecuador.

International VLBI Service
G. Tuccari

For more details see the web site: www.iag-aig.org and “The Geodesist’s Handbook 2012” (JoG No.10, Vol.86, Oct.2012).

List of Acronyms

ASI	Agenzia Spaziale Italiana
IGM	Istituto Geografico Militare
CNR	Consiglio Nazionale delle Ricerche
INGV	Istituto Nazionale di Geofisica e Vulcanologia
OGS	Istituto Nazionale di Oceanografia e di Geofisica Sperimentale
PoliMi	Politecnico di Milano
PoliTo	Politecnico di Torino
UniBo	Università di Bologna
UniRoma	Università di Roma “La Sapienza”
UniPg	Università di Perugia
UniPd	Università di Padova
UniTs	Università di Trieste
UniTn	Università di Trento
UniMo	Università di Modena



ITALIAN GEODETIC RESEARCH ACTIVITIES IN THE PERIOD 2013-2015

IAG REPORT

BY F. SANSÒ
ITALIAN DELEGATE TO IAG

Co-authored by:

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(6) Politecnico di Torino,
(7) IGM,
(8) Università di Modena,
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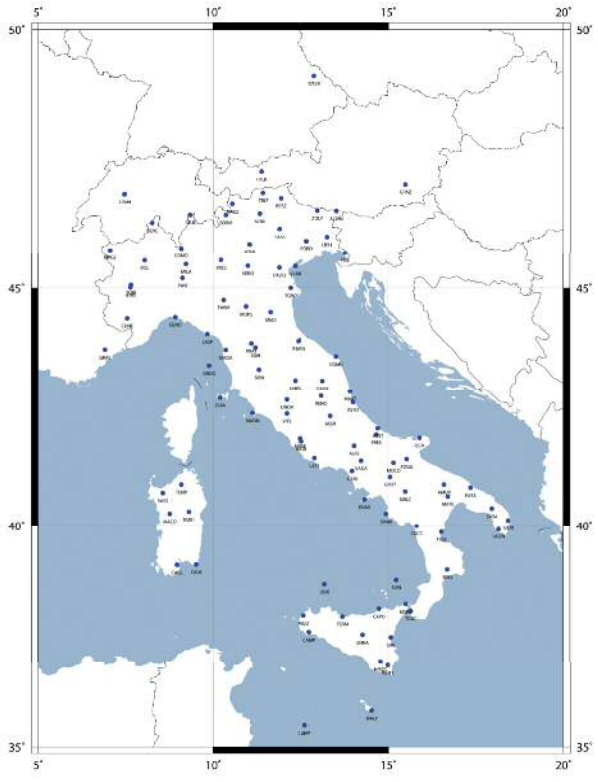

International Association of Geodesy (IAG) by Fernando Sansò

Activities in Italy (2013-2015)

Short summary
The report is organized by 4 IAG_Commissions, the Inter-Commission Committee on Theory and the Services.
For each of them we report: name, contact persons, participants to structures, scientific reports, bibliography.

Structures:

Commission 1 **(Reference Frames)**

Contact persons A. Caporali
G. Bianco
R. Maseroli

Participants to IAG Structures

JWG **1.1** on ties of Space Observations
P.Sarti (Chair)
C. Abbondanaza
G. Bianco
L. Vittuari

WG **1.4.2** on celestial reference frames
V. Tornatore

Italian Institutions

ASI
IGM
CNR
Universities (PoliMi, PoliTo, UniBo, UniRoma, UniPg, UniPd)

Summary
Activities related to the establishment and maintenance of the Terrestrial Reference Frame, from both the instrumental and the theoretical point of view.
Particularly relevant is the participation of ASI to the various IAG Services. Also the theoretical discussion on the relation and simultaneous modelling of deformations of the Earth surface and of the variation of the Earth orientation parameters in a terrestrial system is relevant.
The implementation of a national reference system into the ITRS has been object of intensive work and Projects of National Interest.

Scientific Reports

Activities of A.Caporali in Geodetic Projects, 2013-2015

1) As Chairman of the CEGRN Consortium (Central European Geodynamics Research Network): Geokinematic investigations in Central Europe using long term data (1994-2013) from epoch and permanent GNSS stations.

2) As Secretary of EUREF IAG Reference Frame Sub-Commission for Europe, integrated in the Sub-Commission 1.3, Regional Reference Frames, under Commission 1 – Reference Frames: Maintenance of the European Reference System and its realizations. Processing standards for GNSS data. Relation to IGS, EuroGeographics and National Mapping and Cartographic Authorities in Europe.

3) As member of the Thematic Working Group 1 (Coordinate Reference Systems) and 2 (2D and 3D geographic grids) of the INSPIRE EU Directive/Annex 1: preparation of the Implementing Rules.

4) As member of the Processing Group of the Rete Dinamica Nazionale (RDN) of IGMI (Istituto Geografico Militare Italiano): maintenance of the RDN at regular intervals.

5) As responsible of the GPS network of the Regione Veneto: maintenance of the 26 GNSS permanent network, alignment to RDN/ETRS89, weekly network adjustment with Bernese 5.2 and IGS/EPN processing standards, analysis of Time Series.

6) As member of the NSPR Project (Network of Permanent GPS stations): weekly computation and adjustment of the network of 400+ GNSS stations in Italy, representing a densification of the RDN. Weekly SINEX files are sent to EUREF for combination and stacking with the EPN normal equations, for densification of the ITRF2008 in Europe. Realization and management of a repository of metadata for 400+ GNSS sites in Italy, Greece for monitoring of data consistency and notification to local network managers.

7) Support to IAG SC1.3 - WG1 Integration of dense velocity fields into the ITRF by sending SINEX files of the Italian network to EUREF for combination and stacking with the EPN normal equations, for densification of the ITRF in Europe.

8) Geophysical modeling of the inferred velocities, correlation of the areas of high strain with structural geology, historical seismicity.

Activities of R.Maseroli in Geodetic Projects, 2013-2015

1) Estimate of the speeds of the Italian Dynamic Network stations (RDN) in the IGb08 frame (absolute speeds) and the ETRF2000 frame (relative speeds to the Eurasian plate) obtained through comparison of periodic calculations of positioning distributed in a period of 5 years (2008-2012).

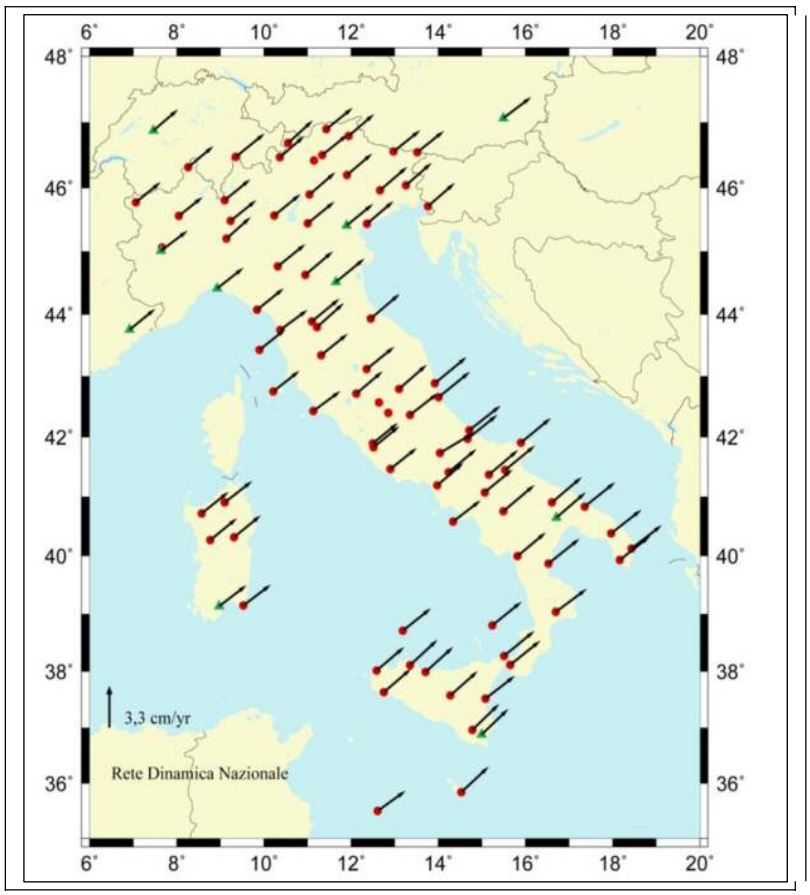

Figure 1 Horizontal speeds in the IGb08 frame (absolute speeds).

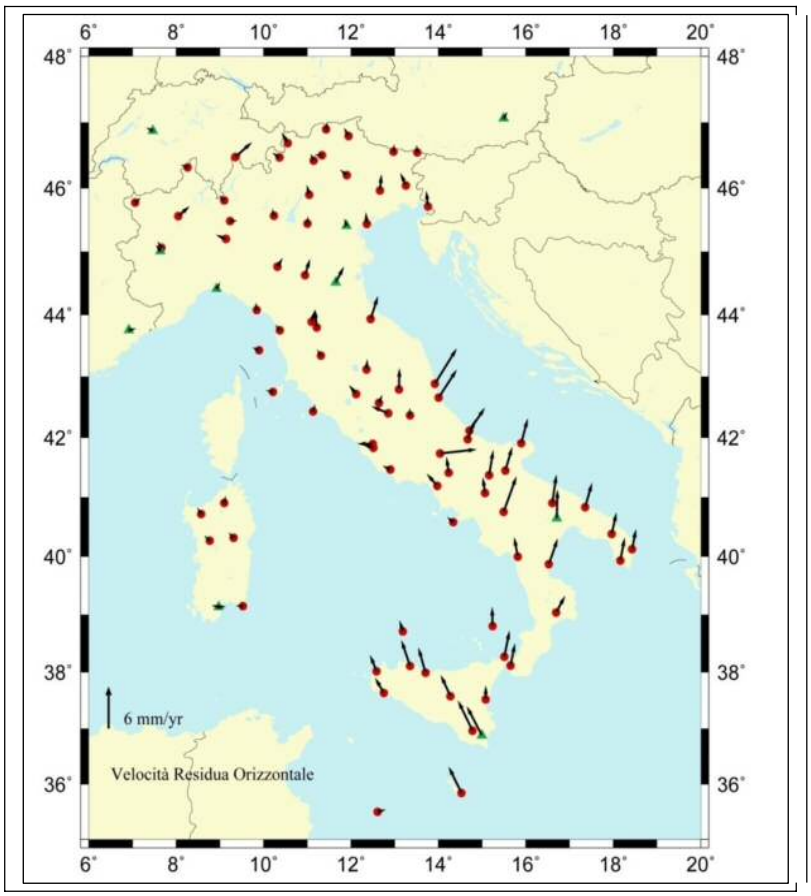

Figure 2 Horizontal speeds in the ERTF2000 frame (relative speeds to the Eurasian plate).

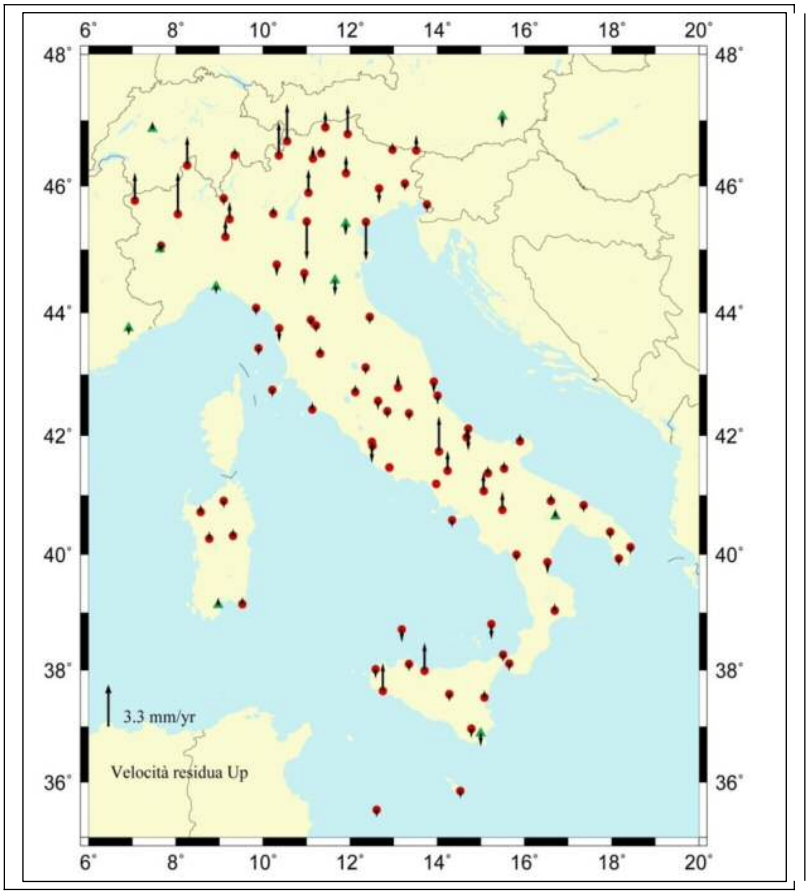

Figure 3 Vertical speeds in the ERTF2000 frame (relative speeds to the Eurasian plate).

2) Update of the RDN (National Dynamic Network) to RDN2. Twenty one disused stations have been replaced, 33 new stations have been added to density the network in areas where the speeds calculation showed interesting geodynamic effects.

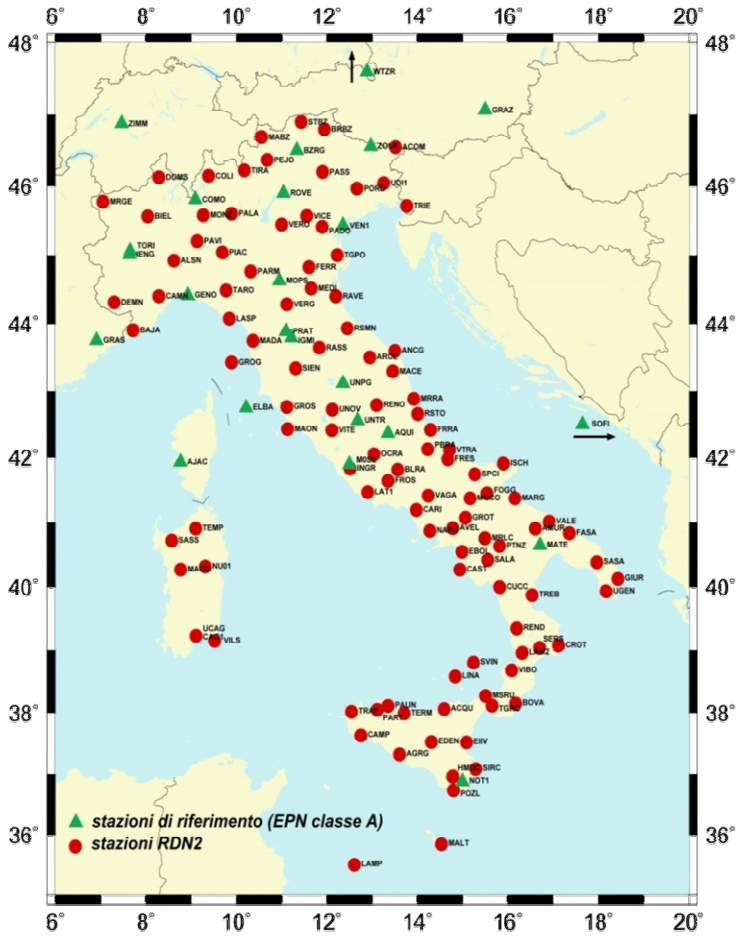

Figure 4 RDN2: 135 GNSS permanent stations

3) Determination of additional 1500 km of Italian high-precision levelling line and updating of their heights.

4) Carry on the computation of the geopotential, the dynamic heights and the normal heights of all the data of the Italian high precision levelling lines, through misures of gravity estimated on the basis of the italian geodetic model ITALGEO2005.

5) Carry on the densification of the points GPS + levelling (about 200 points), for the future improvement of the Italian geoid model.

6) Grids (in NTv2 format) containing the differences between the geodetic reference systems used in Italy (ROMA40, ED50, ETRF89, ETRF2000), accepted by leading commercial and free GIS softwares.

Activities of G.Bianco in Geodetic Projects, 2013-2015

The ASI Space Geodesy Center "G. Colombo" (CGS) has contributed to the IERS Technique Centers (ILRS, IVS, IGS/EUREF) since the beginning of the Service activities both in its role of fundamental station and analysis center.
The ILRS Governing Board recognized ASI/CGS' continuous and rigorous contribution and appointed it as one of the official ILRS Analysis Centers (ACs) when the ILRS AC structure was finalized (2004). In June 2004 the Center was selected by the International Laser Ranging Service (ILRS) as its primary Official Combination Center (CC) for station coordinates and Earth Orientation Parameters.

ASI/CGS is an official IVS Station, Data Center since the beginning of the service (1999) and Analysis Center since 2011.
ASI/CGS is operating as EUREF LAC since 1996, producing since then the requested solutions for the European reference frame densification and tropospheric applications, In 2009, ASI-CGS became also an EPN Regional Broadcaster for the dissemination of Real Time orbit and clock corrections as well as observation streams Since 2012 ASI/CGS is participating to EUREF Technical Working Group.
In January 2012 a GNSS receiver has been installed in the framework of the IGS Multi-GNSS (M-GEX) experiment.
In 2012 the EUREF Technical Working Group invited ASI/CGS expert to become its member, recognizing ASI/CGS' continuous and rigorous contribution as EPN Local Analysis Centre delivering final, rapid and hourly solutions for the European Reference Frame densification and tropospheric applications. In 2014, at the EUREF Symposium, ASI/CGS was appointed as EPN Tropospheric coordinator.
ASI/CGS has been participating since 1999 to many GPS Meteorological projects (COST 716, MAGIC, TOUGH, E-GVAP) and is presently participating to E-GVAP III (2009-2013, contribution to the operational meteorology) as Analysis Center and Combination Center and to the COST Action ES1206.
In January 2010 ASI/CGS has been appointed as GGOS Coordination Office
Information on the CGS and some of the analysis results are available at the CGS WWW server GeoDAF (Geodetic Data Archiving Facility, http://geodaf.mt.asi.it).

SLR Data Analysis

ILRS Activities

In the years 2013-2014, ASI/CGS has been deeply involved in the ILRS activities, mainly in support of the reference frame maintenance and under the coordination of the Analysis Working Group, .Due to its double role of Analysis Center and Combination Center, ASI/CGS provides both its single AC solution and the combined product of the official ILRS ACs (actually 8), whenever requested. Main projects:

- **Official ILRS Products**: Weekly and Daily site position and Earth Orientation Parameters obtained using LAGEOS and ETALON data. The solutions provide the weekly coordinates of the worldwide SLR tracking network and the daily EOPs as ILRS contribution to the USNO Rapid Service.
- **ITRF maintenance**: long term time series of site coordinates and EOPs computed according to the requirements of the IERS inter-technique Combination Centers. The ILRS contribution to ITRF2014 has been delivered following the guidelines of the IERS Call for Participation: a time series of coordinates and EOP over the 1983-2014 time span.
- **IERS Pilot Project** to evaluate the impact of non-tidal atmospheric loading at the observation level.
- **Pilot Project on Weekly orbits:** satellite ephemerides for Lageos and Etalon, preliminary periodic evaluation/comparison of the ACs weekly orbits in order to produce a combined official product.
- **Station qualification:** ASI/CGS is one of the ACs designated by the AWG to validate the data from new or upgraded sites or after an earthquake.
- **Bias monitoring:** routine activity carried out to compute data corrections whenever the biases are not reported by the station, in close contact with the station engineers.

IERS contribution: production of EOP time series regularly performed as ASI/CGS operational EOP series:

ETRUSCO-2 Project: characterization and validation of the optical performance of satellite Laser Ranging Arrays under laboratory-simulated space conditions.

ASI/CGS internal projects:

The ASI/CGS SLR analysis activities extend beyond the accomplishment of its role within ILRS/IERS and were addressed in the following main application fields.

- **Reference Frames:** annual generation of multi-year solutions from Lageos I and II data, used as a benchmark for global network coordinates/velocities EOPs, satellite ephemerides and accelerations, site biases.
- **Gravity**: long term time series of low degree Earth's geopotential coefficients and geocenter.

VLBI Data Analysis

IVS Activities

In the years 2013-2014, ASI/CGS has been deeply involved in the IVS projects:

- **Session Earth Orientation Parameter Series:** Time series of X pole, Y pole, UT1, Xp rate, Yp rate, UT1 rate, dpsi, and deps.
- **Terrestrial Reference System (TRF):** Set of station positions, velocities, and correlations.
- **Celestial Reference System (CRF)** Set of right ascension and declination for sources.
- **Tropospheric Parameters:** Regular submission of tropospheric parameters for all VLBI stations observing in the IVS R1 and R4 sessions the results are available on the IVS products ftp sites.
- **Daily Solution Files** operational submission for each 24-hour session to provide earth orientation and site positions, the covariance matrix of the estimates and decomposed normal equations.
- Contribution to IVS combination for ITRF2014.

IERS Contribution Regular submission to the IERS EOP operational series of R1 and R4 session EOP estimates

ASI/CGS internal projects:

- **Global VLBI Solutions:** Every year, global VLBI solutions are produced, including all the observation sessions since 1979 onwards. The estimated parameters of the global solution are:
  - Celestial Frame: right ascension and declination as global parameters for 637 sources
  - Terrestrial Frame: Coordinates and velocities for 92 stations as global parameters
    - Earth Orientation: Unconstrained X pole, Y pole, UT1, Xp rate, Yp rate, UT1 rate, dpsi, and deps.

GPS Data Analysis

EUREF/IGS Activities

In the years 2013-2014, ASI/CGS has been deeply involved in the EUREF activities, mainly in support of the reference frame maintenance. Main projects:

- **Official EUREF Products**:
  EPN Final weekly product: site coordinates and tropospheric parameters using IGS Final products, now covering a European sub network of 41 sites, 2-week latency
  EPN Rapid daily product: site coordinates using IGS Rapid products, now covering a European sub network of 41 sites, 1-day latency
  EPN NRT hourly product: site coordinates using IGS Ultra- Rapid products, now covering a European subnetwork of 41 sites, 1-hour latency
- **EPN Real Time Analysis:** ASI-CGS is an EPN Regional supporting the dissemination of RT orbit and clock corrections and observation streams it contribute directly to the data stream with 3 RT GNSS stations.
- **EPN Reprocessing:** Reprocessing the EPN Network from 1996 onwards.

- **EPN Tropospheric Product:** Combination of the tropospheric products of the different EPN analysis centres for the generation of the combined EPN station zenith path delay solutions.

IERS contribution: operational submission to the IERS EOP operational series of GPS daily EOP estimates

GNSS Meteorology Activities

In the years 2013-2014, ASI/CGS has been deeply involved in the GNSS-Met activities as E-GVAP Analysis Center and Combination Center.

- **Official E-GVAP Products**:
  NRT ZTD estimates: every hour, 15' ZTD estimates with a 1h45' latency for an European network of more than 200 sites are produced;
  NRT ZTD combined estimates: every hour, the 15' ZTD estimates from the contributing E-GVAP Analysis Centers are combined and made available to the project, using a combination SW developed at ASI-CGS.
  Quality Control: on hourly basis AC bias w.r.t. the combined solutions are computed providing a quality indicator for each solution.

ASI/CGS GNSS-Met activities in support of NWP applications, nowcasting and forecasting of severe weather events will continue, in the following years, in the framework of E-GVAP phase III and of the EU COST Action "Advanced Global Navigation Satellite Systems tropospheric products for monitoring Severe Weather Events and Climate" (GNSS4SWEC).

ASI/CGS internal projects:

ASI/CGS GPS analysis activities extend beyond the accomplishment of its role within EUREF and E-GVAP and were addressed in the following main application fields.

- **Reference Frames:** annual generation of multi-year solutions of site coordinate and velocity of a GNSS network covering the central Mediterranean area.
- **Zenith Tropospheric Delays (ZTD) Residual Fields:** hourly generation of ZTD residuals fields covering the central Mediterranean area.
- **Integrated Water Vapour Fields:** hourly generation, 15 min resolution, of Integrated Water Vapour fields covering the central Mediterranean area.

Multi-technique Data Analysis

COL Working Group: submission of requested weeks (CONT-08 and -11 campaigns) for SLR solutions in the form of NEQ SINEX and participation to the WG activity.

ASI/CGS internal projects:

- **Gravity**: long term time series of degree 2 Earth's geopotential coefficients variations obtained from SLR and VLBI EOP estimates, through excitation functions and time/frequency comparison with Angular Atmospheric and Oceanic Momenta components (from IERS dedicated sub-bureaus).
- **EOP excitation functions** Regular production of the daily geodetic excitation functions from the ASI/CGS estimated EOP values for IERS (SLR, VLBI), since 2006.
- **Geodetic solution combination** Realization, implementation and testing of combination algorithms for the optimal merging of global inter- and intra-technique solutions and of regional (e.g. Mediterranean) solutions to densify tectonic information in crucial areas.

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SC 2.6 Gravity and Mass Displacements
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JWG 2.1 Techniques and metrology for absolute gravity
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JWG 2.2 Absolute gravity
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JWG 2.3 Assessment of GOCE models
R. Barzaghi

JWG 2.4 Interpretation of Tibet, Xinjiang and Siberia
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JWG 2.8 Inversion of gravity with solid Earth coupling
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OGS
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Summary

A lot of work has been done in conjunction with ESA structures and NGA and the item of global and local modelling of the gravity field, in particular to estimate local geoids including the new data sets coming from the Goce mission. Also the GOCE Italy project has been developed, with several geophysical and geological and oceanography applications.

Scientific Reports

Activities of R. Barzaghi and M.Reguzzoni in Geodetic Projects 2013-2015

Gravity field estimation using satellite and ground based data

Ground based gravity data have been combined with satellite data to get an improved estimate of any functional of the anomalous potential T. GOCE T_{zz} observations available at ESA have been combined with radaraltimetry and gravity anomalies at ground level using collocation. In performing the collocation estimate an improved covariance fitting procedure has been devised and applied. In this way an integrated estimate of the geoid has been obtained and tested versus available GPS/leveling data. The performed tests in the Central Mediterranean area have provided reliable estimates.

The Italian gravity database has been then used to estimate gravity along the Italian levelling lines. This allowed the estimation of the gravity corrections (dynamical, orthometric and normal) to properly correct the simple levelling increments. This has been done in cooperation with IGM that supplied the raw levelling increments of the first order Italian levelling network.

(R. Barzaghi, B. Betti, D. Carrion, G. Gentile, R. Maseroli, F. Sacerdote. Orthometric correction and Normal heights for Italian levelling network: a case study. Applied Geomatics , Vol. 6, 17-25, 2014).

Furthermore a project for geoid estimation in the Mediterranean area started in cooperation with most of the nations of the area. This project, managed at Politecncio di Milano, will allow the computation of a detailed geoid which will be profitably used for e.g. estimating a reliable DOT over the Mediterranean Sea.

Deflection of the vertical estimation

Deflection of the vertical estimation has been performed based on gravity data. This allowed a properreduction of observed zenith and azimuth angles measured in a precision traverse for estimating reference pointcoordinates in the Gran Sasso Laboratories. These reference points on the Borexino, Icarus and LVD experiments have been used in the context of international experiments aiming at re-estimating the neutrino velocity based on neutrino beams from CERN.

Another test on deflection of the vertical was done to assess its impact on aerial navigation (R. Barzaghi, M. Pepe, G. Prezioso. The estimation of the deflection of the vertical for improving aerial surveys: a comparison between EGM08 and ITALGEO05 estimates. Submitted to Acta Geophysica).

Height datum problem

The global height datum problem, that is the determination of biases of different height systems at global scale, has been revised and one solution has been proposed. In this approach height anomalies derived from GNSS ellipsoidal heights and biased normal heights have been compared with height anomalies derived from an anomalous potential which combines a satellite-only model up to degree 200 and a high-resolution global model above 200. Numerical tests have been devised to prove the effectiveness of this method and an error budget has been performed. Also, at local level, GOCE data has been used to unify the Italian and Swiss geoids in the framework of the HELIDEM project. Further studies are ongoing.

Satellite geodesy

Analyses on satellite gravity missions have been performed with particular attention to the data analysis of the GOCE mission for gravity global and local model estimation and for geophysical applications.

Aerogravimetry
This research aims at local gravity field modeling taking advantage of GOCE data for the low frequency part of the field and improving the acceleration estimation by the nowadays available GNSS constellations.
Furthermore, an aerogravimetry test has been performed over the Italian area in the framework of the GEOHALO project (a joint project of several universities and research institutions from Germany, Switzerland and Spain). The surveyed zone covers the Central-South part of Italy, roughly from latitude 36°N to 44°N. In this area, seven main tracks NW to SE were surveyed having a spacing of about 40 km and an altitude of 3,500 m, complemented by an eighth track in an altitude of 10,000 m. Four perpendicular cross tracks were also added.
The investigation aimed at defining the spectral properties and the level of accuracy and precision of the observed gravity data. Comparisons with gravity anomalies predicted from Italian ground data were performed at Politecnico di Milano. The gravity field in the surveyed area as derived from ground data is propagated to the aerogravity survey points and compared to the observed gravity anomalies. Upward continuation is performed using the remove-restore approach and collocation. The obtained results proved that the GEOHALO gravity data can profitably be used in checking and improving ground gravity databases.
(R. Barzaghi, A. Albertella, D. Carrion, F. Barthelmes, S. Petrovic, M. Scheinert. Testing airborne gravity data in the large-scale area of Italy and adiacent seas. Submitted to the Proceedings of the IGFS Meeting (IAG Series) in Shanghai).

Crustal deformation laboratories
The network of stations with underground deformation measurements in North-eastern Italy is maintained. The three stations house tiltmeters and extensometers, including the famous Grotta Gigante „Long-base Pendulums“ in the Trieste Carst. This station has an exceptionally long continuous data series of near to 50 years. The research includes free oscillations of modern mega-earthquakes compared to the historic Chile 1960 event. Further the underground hydrology is studied through the induced tilt signals.

GOCE observations for the detection of natural resources.
GOCE has revolutionized the knowledge of the gravity potential field in remote areas. The studies include sensitivity analysis of GOCE for geologic structures relevant for oil and mineral exploration. Methodological aspects are studied to define the best way to extract the geological signal from the GOCE observations using either the on-track gradient observations or the derived global gravity models. Software has been developed, including the modeling of tesseroids and for the inversion of the crustal density inhomogeneities. The methods have been applied to Africa, South America and Alps, demonstrating the huge leap ahead that GOCE has delivered for the use of potential methods in exploration in remote areas.

Computation of the space-wise solution, now consisting in spherical grids of GOCE-only gravity gradients at mean satellite altitude with their error estimates. The approach has been improved in many respects and in particular in the along-orbit filtering, coupling the Wiener filter with a whitening filter, and in the spatial gridding, defining clouds of points with a suitable data density around each grid knot. From the estimated global grids, a set of spherical harmonic coefficients can be straightforwardly derived by numerical integration plus some additional regularization. The global grids have been delivered to ESA under the HPF (High-level Processing Facility) contract, while the spherical harmonic coefficients have been uploaded to the ICGEM (International Centre for Global Earth Models) website. Both types of product have been delivered with the corresponding error information by Monte Carlo simulation.

Studies and computation of combined global models at high resolution. In particular a combination between GOCE and EGM2008 has been implemented exploiting all the publicly

available error information of the two models. This combination has been computed both at global and local level (Mediterraean Sea).

Studies and simulations on the solution of the height datum problem using satellite-only models (based on GOCE and GRACE) complemented with EGM2008, and GPS-levelling data. The problem has been studied at global level by simulations and at local level in the case of the unification of the Italian height datum, namely the ones of Italian mainland, Sicily and Sardinia. An alternative procedure to directly merge local geoids on the basis of satellite-only global models has been studied and applied to the Italian/Swiss case.

Computation of global Moho models and more generally global crustal models using GOCE data, possibly combined with seismic information. In this framework it is remarkable the computation of the so-called GEMMA (GOCE Exploitation for Moho Modelling and Applications) model, delivered the community by a suitable WPS (Web Processing Service). GOCE data have been also used for regional Moho determination. A Bayesian approach for local gravimetric inversion based on MCMC (Monte Carlo Markov Chains) methods have been studied too.

Computation of a global MDT (Mean Dynamic Topography) by subtracting a GOCE-based geoid from a given altimetric MSS (Mean Sea Surface). After properly filling the continents, a Wiener filter in spherical harmonics has been implemented to smooth the MDT. Geostrophic currents have been consistently derived by using a spherical harmonic expansion. The same procedure has been applied in the Mediterranean Sea, here using a least-squares collocation approach for the smoothing. The errors of the MDT and the geostrophic currents are computed by propagating the prevailing block-diagonal structure of the error covariance matrix of the GOCE coefficients.

- **Funded projects**

In the following, the main funded projects related to gravity researches are briefly described:

GOCE-HPF (High-level Processing Facilities): funded by the European Space Agency (ESA), it involves European university and research centers with the final aim of producing Level 2 GOCE data and estimating a global model of the Earth gravitational field. Politecnico di Milano is responsible for the model by the space-wise approach and it is now computing global grids of gravity gradients at mean satellite altitude that should have a higher local content than the one of the spherical harmonic coefficients.

GOCE-ITALY: funded by the Italian Space Agency (ASI), it involved Italian university and research centers with the final aim of exploiting GOCE data for applications in geodesy (combinations between GOCE and other global and local gravity models also based on ground data, height datum unification at global and local level, etc.), geophysics (modeling of unknown crustal structures, local and global Moho estimation, megathrust earthquake modeling) and oceanography (Mediterranean Sea circulation).

GEMMA (GOCE Exploitation for Moho Modeling and Applications): co-funded by ESA-STSE and ASI, the main goal of the project was to map the crust-mantle discontinuity (Moho) all over the world and in key regions by means of GOCE data. The obtained Moho is also based on ETOPO1 and a 1°x1° sediment model for the shallowest layers. The crust is divided into geological provinces, each of them characterized by its own relation between density and depth. The GEMMA Moho is freely available and delivered with the support of a Web Processing Service (WPS).

GAL (Galileo for gravity): funded by the European Community, it is a project of aero-gravimetry based on the joint used of positioning techniques, such as GPS, EGNOS and in particular Galileo

systems, inertial measurement units (IMUs) and satellite gravity data and global models derived by the GOCE mission for the estimation of low frequency part of the gravity field; the proposed solution does not make use of on board gravimeters.

VIKING (Very Improved KINematic Gravimetry): funded by ENI, it is a project with the aim of improving performances of airborne kinematic gravimetry in terms of accuracy and spatial resolution of the retrieved local gravity field; this is done by fully exploiting the current state of the art satellite technology (GNSS multi-constellations), IMUs, on board gravimeters and innovative processing strategies.

DPC 2012-2013: in the framework of the seismological projects of INGV, activities have been performed to enhance the Italian ground gravity database with the low frequency information coming from the GOCE mission; this has been done for the Po Plain area. The final aim of these activities was to investigate the crustal velocity and density 3D modelling in the Po Plain, with the support of GOCE satellite gravity data too.

Activities of C.Braitenberg in Geodetic Project 2013-2015

Crustal deformation laboratories
The network of stations with underground deformation measurements in North-Eastern Italy is maintained. The three stations house tiltmeters and extensometers, including the famous Grotta Gigante „Long-base Pendulums“ in the Trieste Carst. This station has an exceptionally long continuous data series of over 50 years. The research includes free oscillations of modern mega-earthquakes compared to the historic Chile 1960 event. The studies on the use of the tilt observations on Karst underground hydrology has been intensified. In cooperation with Dr. Devoti (INGV) the joint analysis of the hydrologic signals in GPS and tilt has been approached and a publication is presently under review.

GOCE observations for the detection of natural resources
GOCE has revolutionized the knowledge of the gravity potential field in remote areas. The studies have been focused in exploiting the high frequency content of the field. Innovative is the reconstruction of the fields for the supercontinent Gondwana. Software has been developed, including the modeling of tesseroids and for the inversion of the crustal density inhomogeneities. The methods have been applied to Africa, Himalaya, South America and Alps, demonstrating the huge leap ahead that GOCE has delivered for the use of potential methods in exploration in remote areas. Applications are in the field of mineral and geothermal resources.

Gravity field of natural caves
We have produced a benchmark dataset of gravity observations and a laser-scan model of the Grotta Gigante cave in the Trieste Karst. The gravity method has been proven useful to identify unknown caves of a threshold size.

Coordination IAG working group

JWG 2.8: Modeling and Inversion of Gravity-Solid Earth Coupling (joint with Commission 3)
Website: http://www.lithoflex.org/IAGc2/
Projects:
GOCE-Italy Project
GOCE – User ToolBox. ESA funded
PERLA – Paraná-Etendeka Regional Lithospheric Analysis. ESA funded project on the exploitation of GOCE gradient data for support of Post-Doc Dr. Patrizia Mariani.

Meetings organization:
18TH INTERNATIONAL SYMPOSIUM ON GEODYNAMICS AND EARTH TIDES
G-ET SYMPOSIUM 2016. Intelligent Earth system sensing, scientific enquiry and discovery
Trieste 5-9 June 2016.
Website: http://www.lithoflex.org/g-et/

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Commission 3 (Earth Rotation and Geodynamics)

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SC 3.5 Tectonics and Earthquake Geodesy
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JSG 3.1 Gravity and height change intercomparaison
S. Zerbini

Italian Institutions

ASI
CNR
INGV
OGS
Universities (PoliMi, UniBo, UniMi, UniMo, UniRoma)

Summary

Most of the activity in the framework of Commission 3 is related to geodynamics and deformation analysis. Particular attention has been devoted to the combination of different techniques in the analysis of post seismic deformation.

Scientific reports

Activities of S.Zerbini in Geodetic Projects 2013-2015

- **ISPRA** Istituto Superiore per la Protezione e la Ricerca Ambientale), for analysis and interpretation of GPS and tide gauge data to study sea-level variations in the northern Adriatic;
- **ASI** (Agenzia Spaziale Italiana) for analysis and interpretation of GPS data and comparison between GPS- and COSMO SkyMedInSAR-derived vertical movements and atmospheric delays. This research work was developed in collaboration with Prof. Claudio Prati of Milano Polytechnic;
- **Eni SpA**. The scientific work concerns the analysis and the geodetic and geophysical interpretation of GPS time series.

Activities of R.Devoti in Geodetic Projects 2013-2015

GPS data processing

INGV is hosting a nationwide GPS network (RING) dedicated specifically to the monitoring of current crustal deformation in Italy. The data are now on public domain and available on-line at ring.gm.ingv.it. All permanent GPS stations in Italy and Europe are routinely processed, using three different software: Gamit, Bernese and Gipsy. Time series and combined secular drifts of the stations are also available on-line.

Geodetic observations at fault scale or local scale

The analysis of the co-, post- and inter-seismic deformation is useful to study the seismic cycle of

seismically active faults. INGV is managing numerous campaign networks and small permanent networks dedicated to study local tectonic and/or volcanic processes (e.g. OMBRA, SAGEONET, CAGEONET projects). A local slope deformation in southeastern Alps (Cansiglio Plateau), monitored with GPS and tiltmeter stations has been intensively studied, that evidenced a transient deformation highly correlated with rainfall (Devoti et al., 2015).

InSAR ground deformations and comparison with GPS
CHARMING ESA-project. The main objective of the project is to investigate whether surface deformation measurements, derived from GPS and Synthetic Aperture Radar data can be successfully incorporated by Probabilistic Seismic Hazard Assessment (PSHA) models and improve their forecast quality.

Combination of geodetic solutions at the normal equation level
The INGV analysis center delivers a combined velocity map of the central Mediterranean region based on the complete reprocessing of all GPS data from 1996 to 2014, with three independent processing schemes (poster EGU 2004).

Activities of A.Capra in Geodetic Projects 2013-2015

The principal activity has been made within the Geodetic Research in Antarctica:

1. Responsible of Italian Geodetic Observatory at MZS.

2. Coordinator of the projects “Geodetic activity for geodynamics purposes in northern Victoria land “ and “ Geodetic Observatory” of PNRA (Italian Program on Antarctic Research” 2009-11.

3. Coordinator of the project “Geodetic and geophysical surveying for geodynamics model of northern Victoria land “ of PNRA (Italian Program on Antarctic Research” 2012-14.

4. Chief officer of SCAR (Scientific Committeee on Antarctic Research) Geosciences Standing Scientific Group till 2012.

5. Chair of GIANT (Geodetic Infrastructure of ANtarctica) SCAR Expert Group since 2012.

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Commission 4 (Positioning and Applications)

Participants None

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Italian Institutions
IGM
CNR
Universities (all Engineering Schools)

Summary
The activities for the framework of Commission 4 are various and range from the study of GPS applications to real time positioning, to navigation, to the use of SAR for ground movements monitoring. A particular mention has to be done for the application of a stand alone GPS to reconstract seismic waveform. Also the development of a free ware navigational software (GoGPS) which is developed under an international cooperation.

Scientific Reports

Activities of A.Manzino in Geodetic Projects 2013-2015

1. Local responsible of the Politecnico di Torino for the PRIN 2008 project with a title" The new Italian geodetic reference system: continuous monitoring and applications to the management and control of the territory."
2. Local responsible of the Politecnico di Torino for the Italy-Switzerland Interregproject HELI-DEM (HELvetia – Italy Digital Elevation Model) related to the unification of the reference systems and the creation of a single digital model of heights.
3. Responsible for GNSS NRTK network managed by Politecnico di Torino and coordinator of the project for the creation of new GNSS Regione Piemonte network for RTK positioning.
4. Local coordinator of the project "Quality Control of GNSS positioning within NRTK networks"

Activities of S.Gandolfi in Geodetic Projects 2013-2015

PNRA – Research program for Antarctic Research
(Operative Unit Geodesy): Studies on Geodynamic and Post Glacial Rebound (PGR) of the VictoriaLand (Antarctica). These studies are carried out by means of space geodetic techniques and inparticular using GNSS. In order to perform correct results interpretation, several methods,approaches and data processing software packages have been used.

(Operative Unit Glaciology): In this contest the geodetic activities are regarding two main aspects.First of all studies on surface deformation of the plateau, by means of GNSS technologies) incorrespondence of two deep drilling sites useful for the dynamic of the two areas. The secondaspects regard all the geodetic activities required for the localization of geophysics survey such asGPR. In particular in this field a lot of studies have been carried out in the Precise Point Positioningfield for static and kinematic surveys.

GNSS Precise Point Positioning
The research is oriented to the definition of the best models and methods, including the aspects related to the useof regional reference network, for high accurate positioning. This research try to focusalso the impact of the windows time observation to the final accuracy. All these tests have beencarried out using GIPSY OASIS II. In this contest a prototype of PPP WEB service has been implemented and under testing (ppp.dicam.unibo.it).

Structural Monitoring
Since two years many studies have been conducted in order to evaluate optimal methods for data processing and filtering of GNSS time series for structural monitoring. For this topics two GNSS permanent station has been installed in the roof of Garisenda Tower (Historical Buildings) and School of Engineering and Architecture of the University of Bologna.

PRIN 2010
In the field of National Program PRIN2010 the geodetic activities are relating to the possibility torealize a prototype of autonomous GNSS permanent station. This prototype constitute the first stepfor the establish a CORS (Continuously Operating Reference Stations) for Emergency.

Activities of M.Crespi in Geodetic Projects 2013-2015

Main research topics
GPS Seismology, high-rate monitoring, kinematic tracking: VADASE, KIN-VADASE
GPS Meteorology: inter-comparison of water vapor estimation approaches
Digital Surface Models generation from high resolution optical and SAR satellite imagery
Imaging Geodesy: exploitation of amplitude signal of high resolution SAR satellite imagery
Indoor Positioning and 3D close range modeling: potentials of low-cost range cameras

GPS Seismology, high-rate monitoring, kinematic tracking: VADASE, KIN-VADASE
VADASE (Variometric Approach for Displacements Analysis Stand-alone Engine) is a new approach to estimate coseismic displacements in a global reference frame in real-time based on a single GPS station technique and on standard GPS broadcast products (orbits and clocks). Since it does not require either additional technological complexity or a centralized data analysis, in principle it can be embedded into the GPS receiver firmware, thereby providing a significant contribution to tsunami warning systems.
VADASE was successfully tested using observations simulated by Spirent simulators, thanks two cooperations with DLR (German Aerospace Agency, Oberpfaffenhofen, Germany) and CATEC (Centro Avanzado de Tecnologías Aeroespaciales, Sevilla, Spain).
The effectiveness of VADASE was then tested on several earthquakes, including the last extremely strong one occurred in Japan on March 11, 2011 (VADASE supplied the first worldwide solution for the displacements at two IGS site (MIZU, USUD) and, at first, was presented at IUGG 2011 General Assembly in Melbourne.
In the last two years the VADASE model, already was extended to Galileo and Glonass, was still refined and thorough compared on real observations with four renown software, used as reference, following different approaches (APP-PPP and CSRS-PPP, Bernese and TRACK), with an agreement at 1-2 cm level, quite close to the agreement between the reference software. Moreover, a comparison between VADASE solution and accelerometer (strong motion) solution was carried out in occurrence of the Emilia (Northern Italy) earthquake, on May 20, 2013.
Thanks to the Galileo extension, a pure Galileo solution based on four Galileo satellites was obtained on April 1st, 2014, and the VADASE Team was awarded the ESA Galileo In-Orbit-Validation Fix Certificate, for one of the first fifty Galileo Fix all over the world.
During the last year both the integration between VADASE and MEMS accelerometer solutions for

oscillatory motions and an extension of the VADASE algorithm for fully kinematic applications were developed (KIN-VADASE).
Moreover, thanks to the development of a cooperation with Leica Geosystems AG, VADASE was implemented onboard a GR10 GNSS receiver and tested at different research centers (UNAVCO; GEONET, Japan; National Cheng Kung University, Taiwan).
Finally, the application of long period VADASE solutions to the detection and study of the free oscillations of the Earth was started and it is under investigation.

GPS Meteorology: inter-comparison of water vapor estimation approaches
The research was developed within an international cooperation with the Universidad Nacional de La Plata (La Plata, Argentina) and the Universidad Nacional de Cuyo (Mendoza, Argentina), partially funded by the Italian Foreign Ministry and the Argentinean Science and Technology Ministry. The goal was the inter-comparison of different approaches to estimate the atmospheric water vapor (WV) both over land and over sea: ground-based approach using GNSS observations, satellite-based approach using radiometer observations acquired in the Jason-1 mission, and model-based using the ECMWF meteorological model.
Following the work already done, a study was developed on the integration between GPS and European Centre for Medium-Range Weather Forecasting (ECMWF) data to derive high spatial and temporal resolution water vapor maps. In the previous studies the ZTD derived by the SIRGAS permanent network were compared with those obtained from the International GNSS Service (IGS) products and from the radiometer on Jason-1 altimeter satellite. The results showed that SIRGAS permanent network can reliably contribute to short and long term meteorological studies. Another previous report analyzed the accuracy of SIRGAS ZTD values in terms of consistency with ZTD values, obtained with ERA-Interim reanalysis model, from the ECMWF database. ERA-Interim is an 'interim' reanalysis to the period 1979-present of all the data stored in the ECMWF database. In the new study, the consistency of the ZTD values obtained from ECMWF and SIRGAS, considering two small areas of South America, was analyzed. The areas chosen were characterized by different features (e.g. homogeneous and heterogeneous orography) in order to better understand their influence on the temporal and spatial variation of ZTD values. The principal objective was the evaluation of the suitability of ZTD values for the application of the collocation method, to obtain the spatial regionalization of the ZTD estimations retrieved by GPS stations. The data from ECMWF, characterized by high spatial resolution but low temporal resolution (3 hours), are elaborated to obtain ZTD data (strictly related to water vapor) with a high spatial resolution. The ZTD values are used to calculate the covariance function, which quantify the spatial variability of ZTD. The covariance function is than used by the spatial interpolation method (collocation method) which is applied to ZTD values obtained from GPS, which are characterized by low spatial resolution but high temporal resolution (15 minutes). It should be possible through this process, to obtain high resolution water vapor maps almost in real time (high temporal resolution). The availability of these high temporal and spatial resolution maps could effectively improve the meteorological forecasts at short-terms (6-12 hours) compared to evaluations done only with data from ECMWF. A procedure was then proposed to optimize the management of data and to organize them in order to facilitate the prosecution of the project.

Digital Surface Models generation from high resolution optical and SAR satellite imagery
The research continued after the conclusion of two international projects (*Evaluation of DEM derived from TerraSAR-X data*, leaded by Prof. Soergel, Leibniz University Hannover, Germany and supported by DLR; *Influence of sensor orientation method, number and distribution of ground control points, image acquisition incidence angles, and strip length on the horizontal accuracy of WV2 satellite orthoimages*, leaded by Dr. Astrand, Joint Research Center European Commission, Ispra, Italy), an international cooperation (Dr. T. Toutin, Canada Center for Remote Sensing, Ottawa, Canada) and the national project (*On the exploitation and validation of COSMO-SkyMed interferometric SAR data for digital terrain modelling and surface deformation analysis in extensive*

urban areas, leaded by Dr. Lanari and supported by ASI-Italian Space Agency).
A rigorous model to orientate optical and SAR imagery coming from different sensors, together with an original (international patent pending) image matching strategy for Digital Surface Models (DSMs) generation from both optical and SAR imagery, and a tool for Rational Polynomial Coefficients generation (based on the rigorous model itself) were implemented in SISAR package. SISAR was thoroughly tested with several high and very high resolution optical imagery and high resolution SAR imagery acquired by COSMO-SkyMed, TerraSAR-X and RADARSAT-2; moreover, it was successfully compared with other software/models.
In the frame of Google Summer of Code 2012 and 2014 programs, thanks to Google grants, they were developed a FOSS tool (under the Opticks environment - https://www.google-melange.com/gsoc/project/details/google/gsoc2012/handreak/5668600916475904) to generate orthoimages from high resolution SAR imagery, and a FOSS tool (under the OSSIM environment) for Digital Surface Models (DSMs) generation complementary to SISAR, in view of the future integration of the two software under the OSSIM environment.

Imaging Geodesy: exploitation of amplitude signal of high resolution SAR satellite imagery
A new branch of research on the exploitation of high resolution SAR imagery for precise positioning and monitoring was opened under the (already in use) name of *Imaging Geodesy*, underlining the strict link between image analysis and precise positioning, basically allowed by the unprecedented orbital and slant-range measurement accuracy of high resolution satellite SAR sensors. This technique, based on the amplitude instead of the phase of the SAR signal, is totally independent from the coherence, whose possible lack strongly affects the DInSAR technique.
Up to know, the goal of our work was to exploit the slant-range measurements, reaching centimetre accuracies, using only the amplitude information of SAR images acquired by TerraSAR-X satellite sensor, whose orbits (Science Orbits) are known at very few centimetres accuracy level as well. The leading idea was to evaluate the positioning accuracy of well identifiable and stable natural and man-made Persistent Scatterers (PS's) along the SAR line of sight. The preliminary results, obtained on the Berlin area (Germany), shown that it is possible achieve a slant-range positioning accuracy with a bias well below 10 cm and a standard deviation of about 3 cm; the results are encouraging for applications of high resolution SAR imagery amplitude data in land and infrastructures monitoring.

Indoor Positioning and 3D close range modeling: potentials of low-cost range cameras
An other branch of research was opened on the exploitation of Microsoft Kinects as close range low-cost user-friendly 3D scanners, able to work in real-time for indoor positioning too. In detail, the aim of this work was to perform the first comparison between Kinect v1 and v2 and to evaluate their potentialities for geomatics applications. A scientific software which automatically measures the coordinates of grid targets in a local Kinect reference system was developed to assess sensors precision and accuracy. Different tests were performed to evaluate the precision dependence on the distance between reference object and sensor; moreover a test field was realized to assess the accuracy. The accuracy resulted at the level of few centimeters for Kinect v1 and around 1 cm for Kinect v2. Overall, Kinect v1 and v2, assisted with the developed software, can be used for real-time close-range 3D modelling at some centimeters and around a centimeter accuracy level respectively.

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2014 Women In Aerospace – European student Award 2013 (Ph.D. Student: Mara Branzanti) – topic: GPS Software Defined Receiver.
2014 Google – 1 Grant for Google Summer of Code – Ph.D. Student: Mara Branzanti (GNSS Software Defined Receiver).
2014 ESA – IOV Certificate for Galileo Fix (VADASE Team).
2014 Google – 1 Grant for Google Summer of Code – Ph.D. Student: Martina Di Rita
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Highlights to the development of Geodetic Theory in Italy 2013-2015

First of all I would like to mention two major events related to Geodetic Theory, held in the period. First the VIII Hotine Marussi Symposium held in Rome on June 17-21, 2013, under the scientific coordination of the Intercommission Committee on the Theory (ICCT) of the International Association of Geodesy.
The Symposium has seen the participation of 83 scientists from 20 countries, with 8 regular sessions and 1 special session held at Accademia Nazionale dei Lincei on the following items:

1. Geodetic data analysis
2. Geopotential modelling, boundary value problems and height systems
3. Atmospheric modelling in geodesy
4. Gravity field mapping methodology from GRACE and future gravity missions
5. Computational geodesy
6. Theoretical aspects of reference frames
7. Digital Terrain Modelling, Synthetic Aperture Radar and new sensors: theory and methods
8. Inverse modelling, estimation theory
9. Accademia Nazionale dei Lincei Special Session: visit at Villa Farnesina, keynote talks and open discussion session

The second event has been an Italian Symposium held at the Accademia Nazionale dei Lincei in Rome on June 3, 2014, with title “Geodesy and Geomatics to the Edge”. In this case the purpose was to collect together geodesists and scientists from Geomatics applications to help them making the point of the development of new frontiers of common interest.
A volume, collecting the presentation of the Symposium is under publication in the collection of the Rendiconti of the Accademia.

Also particularly significant has been the publication of the Springer book “Geoid Determination”, of which the writer is the major author. In this book for the first time a comprehensive exposition of the modern approximation theory of the gravity field and related mathematical problems, has been accomplished.

As for new results achieved in geodetic theory, the following can perhaps be mentioned:

- a refinement of the classical geodetic boundary value problem has been done;
- a new much more general mathematical analysis of the inverse gravimetric problem has been achieved, with internal distributions either in Banach Spaces or in spaces of distributions;
- a new Bayesian approach to the inverse gravimetric problem, with prior geological information has been proposed and is presently under numerical development;
- a theory for the exact alignment of local and global networks, rigorously taking into account intra-frame and inter-frame covariances has been developed, proving that significant differences in the estimates particularly of the velocities, with respect to non rigorous adjustment can be found.

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Global Geodetic Observing System - (GGOS)
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Services

International Gravity Field Service - (IGFS)
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I. Marson (Boureau)
F. Coren (Boureau)

International Geoid Service – IGeS
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The main IGeS scientific activities in the period 2011-2015 have been related to two research areas: the methods for merging local geoid estimates; the analysis of the global height datum. Both problems are strictly related to the IGeS mission that is focussed on local/regional geoid estimation and evaluation. Theoretical solutions to the two problems have been devised and tested on numerical examples in order to prove their feasibility. Furthermore, the support activity on geoid computation continued. IGeS has co-operated with the Centre for Geodesy and Geodynamics of Nigeria in giving a training course on geoid estimation theory and geoid estimation software. IGeS also was supporting the computation of the geoid in the San Paolo state in Brazil. Finally, IGeS web site was totally renewed and the local geoid solution database was improved by adding new local solutions (namely the Switzerland geoid, the French geoid, the new European EGG2008 geoid and the US geoid). Geoid Schools were also planned and organized. In October 7th- 11th 2013 at the Universidad Tecnica Particular de Loja in Loja (Ecuador) the last geoid school was held according to the following program:

- Heights, height datum and Boundary Value Problems (F.Sansò)
- Global geopotential models and their use (N.Pavlis)
- Modelling the topographic effect (D.Blitzkow)
- Local improvements of the geoid (R.Barzaghi)
- Height datum unification (M.Sideris)
- Vertical Datum Standardization (L. Sanchez)

Furthermore, a special issue of the Newton's Bulletin will be issued on GOCE models testing that will be prepared for the next IAG/IUGG General Assembly in Prague.

International VLBI Service
G. Tuccari

List of Acronyms

ASI	Agenzia Spaziale Italiana
IGM	Istituto Geografico Militare
CNR	Consiglio Nazionale delle Ricerche
INGV	Istituto Nazionale di Geofisica e Vulcanologia
OGS	Istituto Nazionale di Oceanografia e di Geofisica Sperimentale
PoliMi	Politecnico di Milano
PoliTo	Politecnico di Torino
UniBo	Università di Bologna
UniRoma	Università di Roma "La Sapienza"
UniPg	Università di Perugia
UniPd	Università di Padova
UniTs	Università di Trieste
UniTn	Università di Trento
UniMo	Università di Modena