Global Geodetic Observing System (GGOS)

http://www.ggos.org

Chair: Markus Rothacher (Switzerland)
Vice Chair: Ruth Neilan (USA)
Vice Chair: H.P. Plag (USA; until March 2010)

Structure

Bureau on Networks and Communications
Bureau on Conventions and Standards
Working Group on Data and Information Systems
Working Group on Satellite and Space Missions
Working Group on Outreach
Working Group on ITRS Standardization
Working Group on Contribution to Earth System Modelling
GGOS Coordinating Office
GGOS Portal
GGOS Science Panel
GGOS Themes
GGOS in the Group on Earth Observation (GEO)

Overview

The idea of a Global Geodetic Observing System (GGOS; originally called IGGOS, Integrated Global Geodetic Observing System) goes back to the IAG Section II Symposium in Munich in 1998. In 2003 at the XXIII IUGG General Assembly in Sapporo the new IAG structure was implemented and with it the GGOS Planning Group was set up. Four years later, at the XXIV IUGG General Assembly in 2007, GGOS was accepted by the IAG Council as a full component of the IAG structure. More details may be found in (Beutler et al., 2009). Table 1 summarizes the major events that happened since, i.e., in the report period 2007-2011. In the following the most important developments are described in some more detail.

Table 1: Major GGOS Events 2007-2011

Date	Event
July 2007	XXIV IUGG General Assembly in Perugia, Italy: GGOS accepted as a full component of the IAG by the IAG Council
January 2009	Establishment of the Bureau on Networks and Communication, Bureau on Standards and Conventions, and the GGOS Portal
July 2009	The book "Global Geodetic Observing System: Meeting the Requirements of a Global Society on a Changing Planet in 2020" published as the basis for the present and future development of GGOS
January 2010	GGOS Coordinating Office starts its work
February 2010	GGOS Retreat in Miami: the three GGOS Themes for integrated products are initiated

December 2010	GIAC (GGOS Inter-Agency Committee) is established
December 2010	GGOS Working Group on Contributions to Earth System Modelling established
January 2011	GGOS Web pages online
February 2011	GGOS Retreat: new vision, mission and goals for GGOS, new GGOS Terms of Reference are set up
June 2011	XXV IUGG General Assembly in Melbourne, Australia: New GGOS chair is appointed by the IAG Executive Committee. Action plans exist for the major components of GGOS.

GGOS 2020 Book

In early 2006 an effort was started to write a book describing the background of GGOS and its perspectives for the year 2020. The final version of this book called "GGOS 2020 book" was published in 2009. This book was realized under the leadership of Hans-Peter Plag and Mike Pearlman with contributions of the GGOS Science Panel as well as a large group of experts in various neighbouring fields of geoscience (Plag et al., 2009). It marks a milestone in the development of GGOS. The full reference is given below.

Building up the GGOS Organizational Structure

The first two years after the establishment of GGOS as a full component of the IAG (the Global Geodetic Observing System of the IAG) were mainly used to build up the structure necessary for GGOS to work. The components to be established were already lined out in the GGOS 2020 book (see Figure 1).

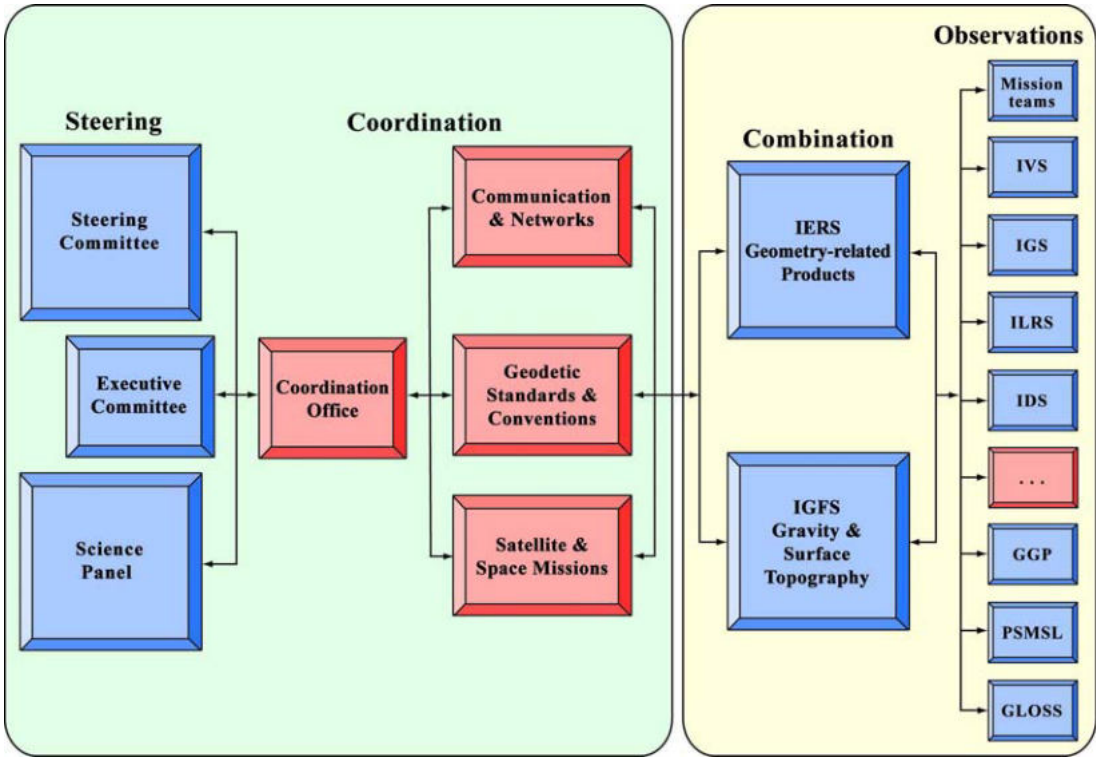

Figure 1: GGOS Structure proposed in the GGOS 2020 Book (Plag & Pearlman, 2009), Chapter 10

In January 2009 the following components could successfully be established:

- Bureau for Networks and Communication: Cambridge Center for Astrophysics / NASA (Director: M. Pearlman)
- Bureau for Standards and Conventions: Research Group on Satellite Geodesy in Munich (FGS: FESG, DGFI, IAPG; director: U. Hugentobler, now D. Angermann)
- GGOS Portal: BKG (Federal Agency of Cartography and Geodesy, Frankfurt; director: Bernd Richter)

For the planned GGOS Bureau for Satellite and Space Missions no leading institution was found and, therefore, the GGOS WG on Satellite and Space Missions was kept. The chair was decided to be C.K. Shum, Ohio State University (OSU). Since 2010, this GGOS WG is led by Isabelle Panet (IGN, Paris) and Roland Pail (TU Munich).

An institution responsible to operate the GGOS Coordinating Office (CO) could be found in the beginning of 2010, when the Italian Space Agency (ASI) volunteered to act as the GGOS CO with Giuseppe Bianco as the director. The GGOS CO is now successfully organizing a lot of the day-to-day activities of GGOS and is also responsible for the GGOS web pages (www.ggos.org) and works closely together with the GGOS Portal at BKG.

With the GGOS CO the organizational structure of GGOS could be completed. In addition, a new GGOS Working Group, the WG on Contributions to Earth System Modeling, was created in 2010 chaired by Maik Thomas at the Deutsches GeoForschungsZentrum (GFZ) in Potsdam. With this new GGOS WG there are now five working groups in GGOS (see Table 2).

An overview of the present structure is also given in Figure 2.

Table 2: Present GGOS Working Groups

GGOS WG	Chair(s)
WG on Data and Information Systems	Bernd Richter, Carey Noll
WG on Satellite and Space Missions	Isabelle Panet, Roland Pail
WG on Contributions to Earth System Modeling	Maik Thomas
WG on ITRS Standardization	Claude Boucher
WG on Outreach	Giuseppe Bianco

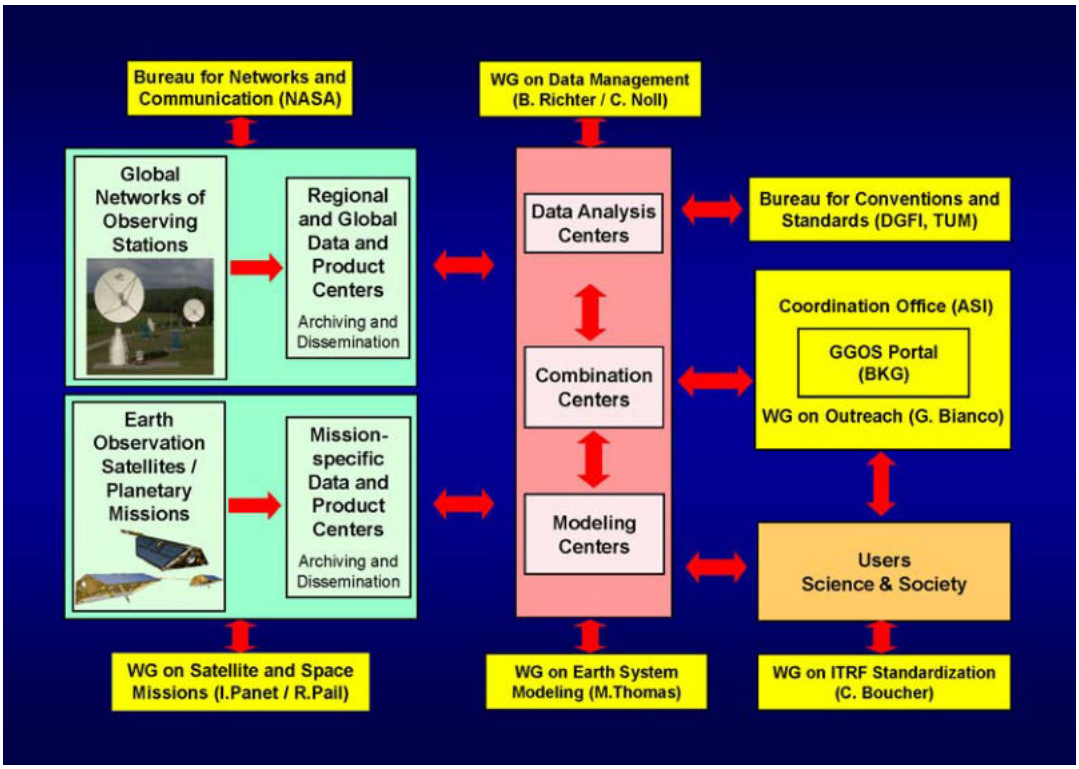

Figure 2: Present GGOS Structure

New GGOS Core Sites

In the period from 1970-1990 a rather rapid development of the global space geodetic infrastructure took place, initiated among others by the NASA Crustal Dynamics Project (CDP). During the years to follow further developments were taking place but only at individual stations, by individual institutions and for individual techniques. Some stations were even decommissioned during this time period. With the arguments of GGOS at hand and due to technique-specific initiatives (e.g. IVS2010, SLR), a new era of building up improved infrastructure has started. Figure 3 summarizes the present status of the GGOS core sites. It can be seen that a substantial progress was taking place during the last few years. In VLBI alone, it is expected that more than 20 new telescopes will become operational in the next several years. This gives an indication that the goal of establishing around 40 global GGOS core sites, as recommended in the GGOS 2020 book, is indeed feasible with the joint effort of GGOS and the IAG Services and the support of the national institutions responsible for the geodetic infrastructure.

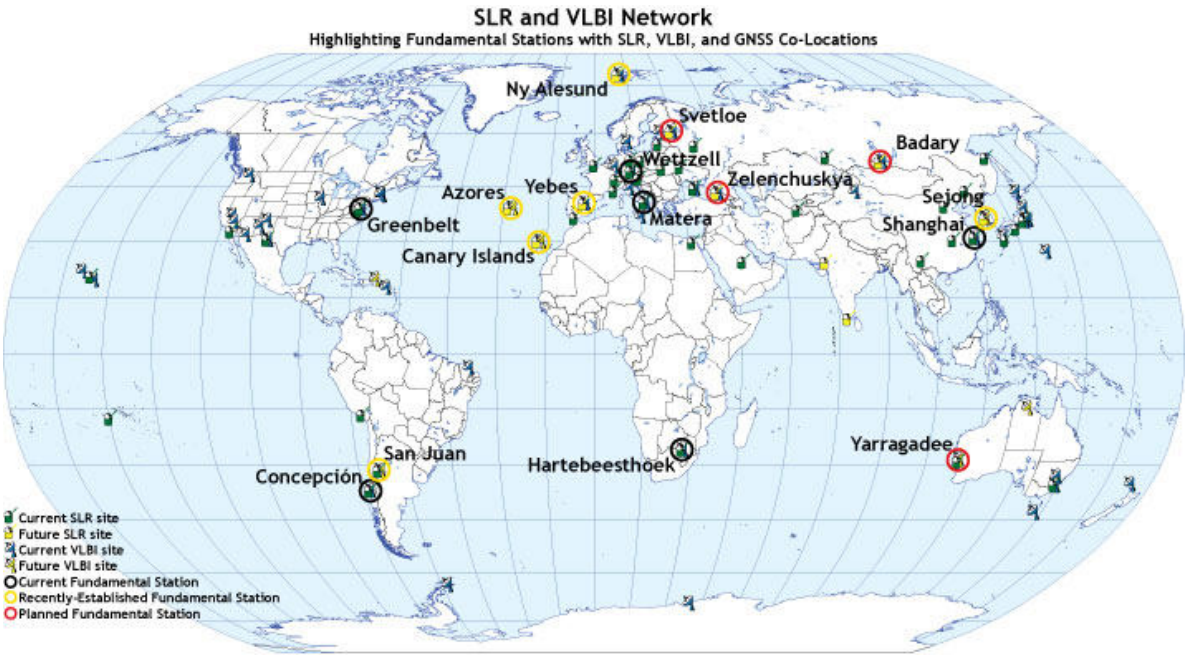

Figure 3: Increasing number of GGOS core sites in the global networks (NASA, 2011)

GGOS Outreach

Besides the GGOS 2020 book several other articles, books and white papers were published during the period 2007-2011.

- Chapter by Blewitt et al., 2010, in the book "Understanding Sea-Level rise and Variability" (Church et al, 2010)
- White papers for the Ocean'09 meeting (Shum et al., 2009; Plag et al., 2009; Scott et al., 2009; http://www.oceanobs09.net/)
- Springer book containing the final report of the German Geotechnologies Project (Flechtner et al., 2011)
- Papers about GGOS (Plag et al., 2010; Plag et al., 2009; …)

In addition, leaflets, posters, one-page stories, and a GGOS booth were produced and presented at various meetings, especially at GEO Plenaries and Ministerial Summits.
Finally, with the help of BKG (Federal Agency of Geodesy and Cartography) the GGOS portal (see below) could be established and new web pages were generated by the GGOS Coordinating Office (ASI).

Retreats, Workshops and Sessions

During the past four years quite a number of GGOS retreats, GGOS workshops and meetings were organized. They are listed in Tables 3 and 4 with their internet link. Whereas the GGOS retreats were held to make progress in the organization and further development of GGOS, the workshops were focussing on specific scientific themes of relevance to GGOS. In addition, GGOS sessions were proposed and held at almost every AGU and EGU Meeting.

Table 3: Retreats organized by GGOS

GGOS Retreat	Place	Date
GGOS Retreat 2007	Oxnard, California	February 19-21, 2007
GGOS Retreat 2008	Bertinoro, Italy	March 25-28, 2008
GGOS Retreat 2010	Miami, USA	February 1-4, 2010
GGOS Retreat 2011	Zurich, Switzerland	February 2-4, 2011

Table 4: Workshops organized or co-organized by GGOS

GGOS Workshop	Place	Date	Web page
The GGOS Contribution to GEOSS and an Observing System for Geohazards and Disaster Prevention	Frascati, Italy	November 5-6, 2007	http://earth.esa.int/workshops/2007Geohazards/
Unified Analysis Workshop 2007	Monterey, USA	December 5-7, 2007	http://www.iers.org/
IGCP 565 Workshop 1: Science of geodetic monitoring of the hydrological cycle	San Francisco, USA	December 11, 2008	http://www.igcp565.org/_workshops/SanFrancisco/
Understanding Glacial Isostatic Adjustment	Espoo, Finland	June 23-26, 2009	http://dynaqlim.fgi.fi/files/GGOS_DynaQlim.htm
Towards a Roadmap for Future Satellite Gravity Missions	Graz, Austria	September 30-October 2, 2009	http://www.igcp565.org/_workshops/Graz/
Unified Analysis Workshop 2009	San Francisco, USA	December 11-12, 2009	http://www.iers.org/
IGCP 565 Workshop 2b: From Satellite Gravity Observations to Products	San Francisco, USA	December 12-13, 2009	http://www.igcp565.org/_workshops/SF_2009/
IGCP 565 Workshop 3: Separating Hydrological and Tectonic Signals in Geodetic Observations	Reno, USA	October 11-13, 2010	http://www.igcp565.org/_workshops/Reno_2010/
Observing and Understanding Earth Rotation	Shanghai, China	October 25–28, 2010	http://202.127.24.12/dct/

GGOS Themes

In view of the complexity of the Earth system as a whole, GGOS decided to start with a small set of integrated and interdisciplinary themes/products of high importance to science and society. The three themes selected are:

- Theme 1: Global Unified Height System (Chairs: M. Sideris, J. Ihde)
- Theme 2: Geohazards (global Earth surface deformations and strain rates for geohazards assessment and disaster prevention) (Chairs: T. Dixon, R. Gross)

– Theme 3: Understanding and Forecasting Sea-Level Rise and Variability (Chairs: C.K. Shum., P. Woodworth)

These themes are described in more details in a later section of this report.

GEO activities

GGOS, representing the IAG in the Group on Earth Observation (GEO), has been contributing to the GEO activities by participating in the GEO Committees and Working Groups and in the GEO Plenaries and Ministerial Summits and by proposing own tasks or subtasks within GEO. The two major subtasks within GEO for which GGOS is responsible are the subtask on "Global Geodetic Observing System" and on "Global Geodetic Reference Frames". These will also be part of the GEO Work Plan 2011-2015, that will be the last GEO work plan before the end of the GEO 10-Year Implementation Plan for GEOSS, the Global Earth Observing System of Systems. Details are given below.

GIAC

In November 2009 a group of national geodetic institutions met for the first time to discuss the establishment of an Intergovernmental Committee for GGOS. This initiative was started by Reiner Rummel (TU Munich) and Dietmar Grünreich (BKG), because the global ground infrastructure for space geodesy is far from ideal and not sustainably financed. Since the GGOS concept builds on long-term observation series, the sustainability of the existing IAG Services and the infrastructure they use is a key issue that needs to be approached.

The Frankfurt Declaration written during this meeting states "The overall goal of this initiative is to improve the sustainability of IAG Services in general and in particular, the long term coverage of the in-situ space geodetic networks in time and distribution and to increase the visibility and effectiveness of Geodesy to global geo-observation programs".

In the time to follow it was decided that before going through the very difficult work of forming a GGOS Intergovernmental Committee (GIC), a GGOS Inter-Agency Committee (GIAC) should be formed. This happened at a meeting of the GIAC Planing Group in San Francisco on December 9, 2010. By now, around 15 major institutions signed the Frankfurt Declaration and became member of GIAC.

GIAC will support GGOS in attaining its goals by working towards an appropriate intergovernmental agreement that facilitates planning, securing, and maintaining geodetic infrastructure and operation of the Services based on the needs of science and society, and by promoting GGOS to international entities that require intergovernmental representation.

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Bureau on Networks and Communications

Chair: M. Pearlman (USA)

Role of the Bureau

The role of the Bureau is to promote the further development of sustained infrastructure needed to satisfy the long-term (10-20 years) requirements for the reference frames and the monitoring of global change signals. GGOS provides observations of variations in Earth shape, gravity field and rotation, which are fundamental for monitoring of climate and global change. The global geodetic reference frame, the International Terrestrial Reference Frame (ITRF) provides the foundation for most Earth metric observations and for observations in the lunar and planetary systems. GGOS provides observations of variations in Earth shape, gravity field and rotation, which are fundamental for monitoring of climate and global change. These observations depend on sustained geodetic ground networks with stations of sufficient measurement quality and global distribution.

The reference frame requirement is to establish an ITRF with an accuracy of 1 mm and a stability of 0.1 mm/year, which represents an improvement of 10-20 beyond the current quality. The main driver for this requirement is the monitoring of sea level, but other applications are not far behind (Plag, H-P and Pearlman, M.R., 2009). These requirements will be met with a ground network of globally distributed stations with co-located VLBI, SLR, GNSS, DORIS, and may include other systems such as gravimeters, seismometers, tide gauges, etc. These have been termed GGOS Fundamental Stations (see Figure 4).

In this role the Bureau will plan and advocate for the implementation of:

- Ground-based network of Fundamental Stations with co-located VLBI, SLR, GNSS, DORIS required to establish an ITRF that has an accuracy of 1 mm and a stability of 0.1 mm/year, which represents an improvement of 10-20 beyond the current quality;
- Implementation of a ground-based GNSS network to make the ITRF of this quality available everywhere on the surface of the Earth for 24 hours a day;
- Implementation of the ground-based tracking network to support planned missions;
- Integration of techniques including gravity field, tide gauges, etc to support GGOS themes.

Progress

- Bi-annual meetings at AGU and EGU the services to exchange information and plans;
  - Files have been implanted to provide on-line access to network station and data product information including local ties, mis-closure files, etc. See: http://observing-system-portal.bkg.bund.de/lang_en/nn_261332/sid_10CCEAF2FA145E6BF8AE876363 B45F00/GGOS-Portal/EN/GGOS-Products/GGOS-Products.html
- Simulation underway to scope the size and properties of the co-location network
  - Thirty globally distributed, well positioned, co-location stations with modern technology and proper conditions will be required to define the reference frame that will meet to requirements;

  - Half of these co-location stations must track GNSS satellites with SLR to calibrate the GNSS orbits;
  - Dense network of GNSS ground stations to distribute the reference frame globally so that users anywhere on the Earth may refer their measurements in the reference frame 24 hours a day.
- IAG services continue to upgrade their technologies and expand their networks
  - SLR: KHz ranging; increased automation, improved electronics;
  - VLBI: new VLBI 2010 design includes much wiser band width, faster slewing;
  - GNSS: multiple constellations, more frequencies, SLR retro-reflectors;
  - DORIS: new ground beacons, additional satellites.
- Co-location network is expanding with the addition of the Yarragadee site, work under-way at Metsahovi, and serious discussions underway at several other sites (see Figure 5);
- The first version of a GGOS Site Requirements Document for co-located (Fundamental) sites is now available, see: http://cddis.gsfc.nasa.gov/docs/GGOSSiteRequirements_ v1.pdf
- Work continues on intersystem vector measurements at co-located sites with the IERS WG on Site Survey and Co-location; these vectors are critical for inter-relating the measurements from the separate techniques;
- Call for Participation for participation in the GGOS network has been prepared and is awaiting a decision by the GGOS Steering Committee and the GIAC;
- Outreach activities have been underway with talks given at AGU, EGU and AOGS, and visits with group interested in implementing a Fundamental Stations including groups in Colombia and Brazil;
- Proposal pending at NASA/HQ to support the completion of prototype VLBI 2010 and SLR systems with a follow-on phase to build and implement a number of units;

Plan

- Continue advocating for the establishment of that GGOS Network of Fundamental Stations; continue the items in process above;
- Continue the simulation activities to quantify the anticipated evolution of the reference frame as a function of phased deployment; systematic errors, additional space objects, tracking scenarios, GRASP satellite for co-location in space, etc.
- Complete the prototype SLR and VLBI and a prototype new technology Fundamental Station at GSFC;
- Issue the Call for Participation periodically to enhance participation and the establishment of partnerships to implement Fundamental Stations.

Deliverables

Although this is a task of promoting and advocating, the goal of this task with the help of the GIAC is:

- Implementation of new technologies at the space geodesy ground stations
- Additional co-located ground stations to expand global coverage

- Improved data quantity and quality for more accurate and stable reference frame and more accurate orbit determination to support active missions
- Improved integrated data products such as the ITRF, sea level, unified global height model, etc.

References

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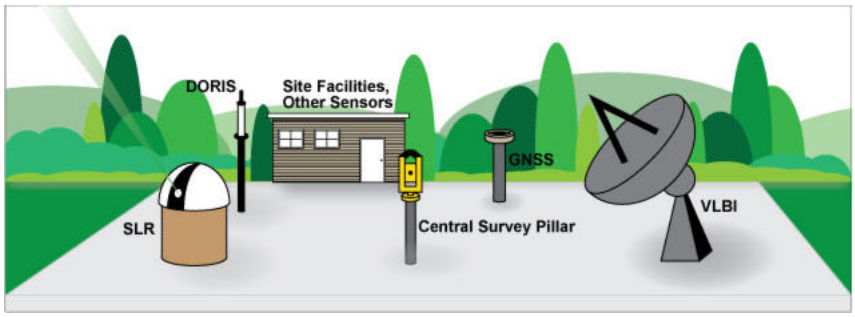

Figure 4: Fundamental Station

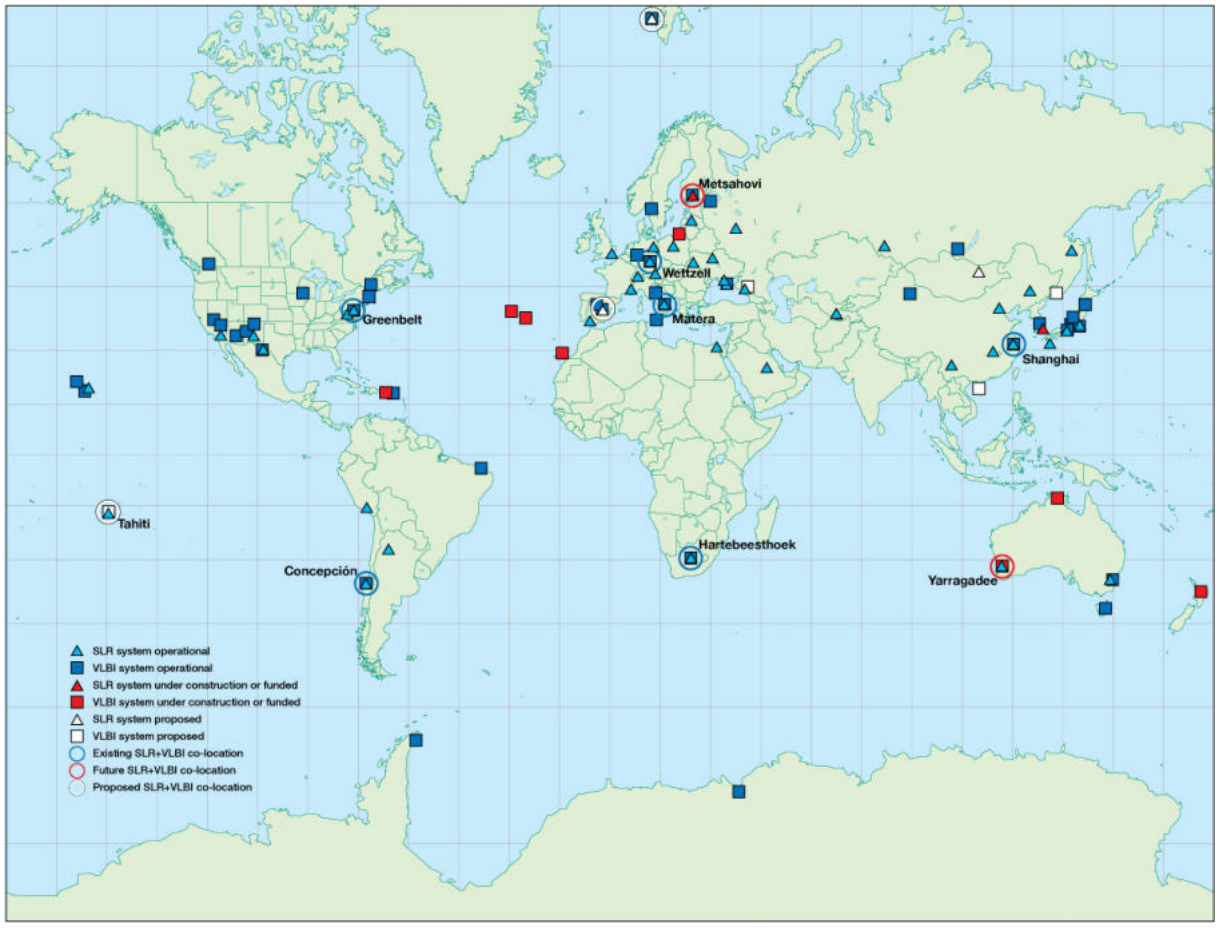

Figure 5: Co-located VLBI and SLR Network. Nearly all stations have GNSS and some have DORIS

Bureau on Conventions and Standards

Chair: U. Hugentobler (Germany)

GGOS WG on Conventions, Models, Analysis

The GGOS WG on Conventions, Models, Analysis (CMA) – the predecessor of the GGOS Bureau on Conventions and Standards – was led by H. Drewes. Objectives of the WG were to ensure the consistency between all (geometric and gravimetric) products by using common standards, conventions and models in data analysis, parameterisation and representation; to improve the geodetic algorithms, parameterisation and physical models to the point, where an overall accuracy and consistency of products better than 1 ppb can be achieved; to stimulate and coordinate efforts aiming at a combined analysis of all space geodetic observation techniques, integrating all parameters common to more than one space geodetic technique.

An extended form was prepared by the WG in order to review the used constants, conventions, models and parameters used by the IAG Services and Commissions and distributed in 2007. The form polled questions on used numerical constants, geodetic conventions, geophysical models, and estimated parameters. Activities included the participation at and contribution to the GGOS Unified Analysis Workshop on December 5-7, 2007, in Monterey, CA. Activities in 2007 and 2008 focused on the analysis of effects produced by the use of different conventions and models on the different estimated parameters in the context of GGOS-D, a cooperative project supported by the German Federal Ministry of Education and Research performed by four institutions (Helmholtz-Zentrum Potsdam Deutsches GeoForschungs-Zentrum, Deutsches Geodätisches Forschungsinstitut, Federal Agency for Cartography and Geodesy, University of Bonn). Further activities were performed in conjunction with research projects related to mass transports and Earth rotation.

GGOS Bureau on Conventions and Standards

The GGOS Bureau on Conventions and Standards was installed in 2009 – as the successor of the CMA – after the acceptance of the corresponding proposal submitted by the Forschungsgruppe Satellitengeodäsie (FGS) by the GGOS Steering Committee Meeting in December 2008. The Bureau is jointly operated by Forschungseinrichtung Satellitengeodäsie (FESG) and Institut für Astronomische und Physikalische Geodäsie (IAPG) of Technische Universität München, Munich, Germany, and the Deutsches Geodätisches Forschungsinstitut (DGFI), Munich, Germany. Members of the Bureau were initially U. Hugentobler (Chair), D. Angermann (Secretary), J. Bouman, M. Gerstl, T. Gruber, B. Richter, P. Steigenberger.

Objectives of the Bureau are to keep track of the strict observance of adopted geodetic standards, standardized units, fundamental physical constants, resolutions and conventions in the generation of products issued by the IAG Services; to review examine and evaluate standards, constants, resolutions and conventions adopted by IAG or its components and propose necessary updates; to identify gaps, inconsistencies, and deficiencies in standards and conventions and to initiate steps to close them; to propose the adoption of new standards and conventions as far as necessary; and to propagate standards and conventions to the wider scientific community and promote their use.

Actions of the Bureau included the compilation of the relevant resolutions, review of the IERS Conventions, comments to numerical constants of IERS Conventions 2010, presentations on standards and conventions and activities of the Bureau at the IAG Scientific Assem-

bly, September 2009, Buenos Aires, Argentina, at the Unified Analysis Workshop 2009, December 2009 in San Francisco, CA, at the Plenary Meeting of ISO TC211, May 2010, in Southampton, UK, and at the IAG Commission 1 Symposium Reference Frames for Applications in Geosciences, October 2010 in Paris.

In order to improve balance between Bureau members affiliated to geometric and gravimetric research fields and to improve the performance of the Bureau the membership was restructured beginning of 2011. New Chair of the Bureau is D. Angermann, Secretary is T. Gruber. Additional members are J. Bouman, R. Heinkelmann, U. Hugentobler, L. Sanchez, P. Steigenberger, affiliated are J. Ihde, J. Kusche. First task was the preparation of the section related to data analysis and combination of the GGOS Action Plan. A main goal is the development of a new geodetic reference system as consistent set of best estimates of geodetic parameters.

Working Group on Data and Information Systems

Chairs: B. Richter (Germany) and C. Noll (USA)

WG Members

– *Bernd Richter chair / IERS /GGOS portal manager* – *Carey Noll chair / ILRS* – *Guiseppe Bianco /GGOS CO* – *Ruth Neilan IGS* – *Laurent Soudarin IDS* – *Pascal Willis IDS* – *Dirk Behrend IVS*	***Geometry***
– *Franz Barthelmes ICGEM* – *Jean-Pierre Barriot ICET* – *Sylvain Bonvalot BGI*	***Gravity***
– *Lesley Rickards PSMSL*	***Sea Level***
– *Felicitas Arias BIPM*	***Time Service***

GGOS Portal

The GGOS portal is thought to provide a unique access point for all data, products and information relevant in the framework of GGOS to serve Earth sciences and applications. Basically, it will provide a platform for services to deliver data, to get and use these data for processing products and to get the products.
GGOS data are classified in three different levels:

- L0 level are all raw data,
- L1 level are all RINEX files (meta data, receiver, station), and
- L2 level and higher are the data and products that are provided by the IAG services) available on the GGOS portal through meta data files on the portal's data base (time series).

Process from L0 to L2 level data: the loose service solution (e.g. IGS, ILRS, IDS, IVS, ...) undergo a transformation into the current ITRF(combination centre) from the raw data into a constrained combined solution (time series), which will be the official solution of these data. The data and metadata of each space technique should be identified through the GGOS portal.
The GGOS Portal basically serves two different kinds of user: data providing user (IAG services and authorised non-IAG institutions) and data consuming user. Generally any registered user can upload data into the portal. Non-IAG institution's data and products will be included into the GGOS Portal only after having successfully passed a review process by the working group DIS and accepted finally by the GGOS EC. Further, each IAG and non IAG service has to specify their data by corresponding metadata.

Web site

The GGOS web site and the GGOS Portal web site will be two independent web sites:

- The GGOS web site will provide information about GGOS, the products and background knowledge to interested user.
- The GGOS Portal will be used as a platform to exchange data and products presented topically ordered (natural hazards, science applications, geodetic applications, satellite missions, techniques and services).

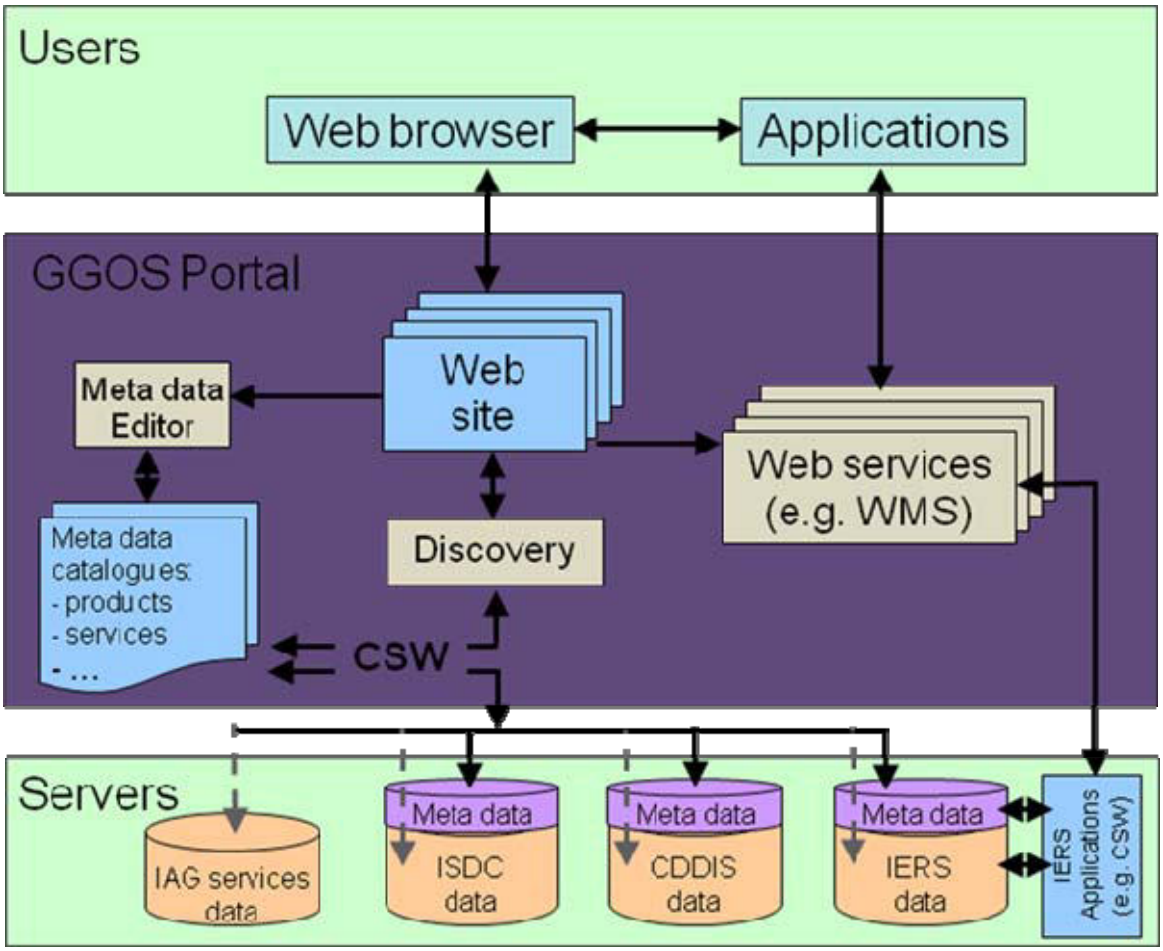

Figure 6: Service oriented architecture of the GGOS Portal

The GGOS Portal is based on service oriented architecture (see Figure 6). A prototype is ready and has been reviewed by the WG DIS and the GGOS EC. The preliminary test version of the GGOS Portals web presentation can be found under http://observing-system-portal.bkg.bund.de. The GGOS web site and the GGOS portal web site cross linked for reference information and data respectively.

In general, the category "Topics" provides general information to the topics specified. To provide the information the WG DIS and the GGOS EC has asked several individuals to detailed information to fill the various fields of interest.

The category "Discovery" will provide the possibility search for data and products based on available meta data.

GGOS Portal Meta Data

Three possibilities for the meta data description were discussed in the EG DIS:

- xml file template provided by the portal manager,
- a meta data block within the SINEX file, which includes not to distribute the SINEX files to the user,
- meta data editor.

For the GGOS Portal the GeoNetwork is embedded into the GGOS Portal web page as meta data editor. The GeoNetwork (see http://geonetwork-opensource.org/) is based on the principles of Free and Open Source Software (FOSS) and International and Open Standards for services and protocols (a.o. from ISO/TC211 and OGC). The use in numerous Spatial Data Infrastructure initiatives across the world guaranteed the long-term support. The GeoNetwork tripod consists of a meta data editor, a search tool and map service interfaces.

The available ISO meta data catalogue has been discussed within the WG DIS and tailored to the necessary geodetic applications. The used fields to describe the individual data are specified in the document presented at the GGOS / IERS UAW workshop in Monterey, Ca.

http://www.iers.org/nn_10902/IERS/EN/Organization/Workshops/Workshop2007MontereyProgramme.html?__nnn=true#doc74712bodyText4 see Sess. 6

"UAW_PosPap_Session_6_GGOS_Portal_and Metadata_Flow_Annexes_1.pdf". Communication by email discussions and working group meeting on May 2, 2010.

Working Group on Satellite and Space Missions

Chairs: I. Panet (USA) and R. Pail (Germany)

December 2008 – November 2010

The GGOS Satellite Mission Working Group (SMWG) is established in December 2008, under the lead of C.K. Shum, and 20 members agreed to serve on this Working Group. An initial Terms of Reference has been drafted.

In August 2009, international collaborations were discussed with James Jong-Uk Park and his colleagues at the Korea Astronomy and Space Science Institute. In August 17–25, C.K. Shum met and discussed with Chinese scientists from Institute of Geodesy and Geophysics, State Seismology Bureau, Shanghai Astronomical Observatory, Institute of Mechanics/Mathematics, in Urumqi and Beijing, China, on GRACE research and China's laser interferometry instrument research and development collaborations. Also their participation in GEO/IAG Future Gravity Field Mission Workshop, to be held in Graz, September 2009, was discussed.

In September 2009, the Working Group jointly submitted an invited abstract to the IAG Symposia, Geodesy for Planet Earth, IAG, Buenos Aires, August 31– September 4, 2009, http://www.iag2009.com.ar/, Sub-Session 7.1: Past Progress and Future Plans, Session 7, The Global Geodetic Observing System: Science and Applications (Convenors: Richard Gross, Hans-Peter Plag, Luiz Paulo Fortes,). The title of the invited paper was: Status and Prospects of the GGOS Satellite Mission Working Group, by Shum et al.

Several Working Group members participated in a joint GGOS/IGCP565 – IAG – GEO Workshop "Towards a Roadmap for Future Satellite Gravity Missions", which was held from September 30 to October 2, 2009, in Graz, Austria. The workshop aimed at bringing together stakeholders in satellite gravity missions in order to establish a roadmap for future satellite gravity missions that outlines the sensor developments, mission concept developments, and mission implementation, and that is consistent with anticipations of the major space agencies, CEOS, and GEO, and with the needs of key user groups (such as IGWCO, the GEO Water Tasks, GOOS and GCOS, Earth scientists, and GGOS itself). The outcome of this workshop is summarized in documents available at http://www.iag-ggos.org/workshops/Graz. It identifies the need for a continuous observation of the time variable gravity field in order to implement an operational observing system for mass redistribution, global change, and natural hazards.

In the course of the workshop, several informal discussions take place with scientists on international collaborations to advocate GRACE Stop-Gap (defined as "mission to extending the current GRACE observational data span using the current GRACE technology and with the possibility to host an experimental laser interferometry sensor, to be launched no later than 2015"), and GRACE follow-on (the laser interferometry satellite-to-satellite tracking) missions. There were extensive discussions of different country/space agencies launching a coordinated GRACE constellation with multiple pairs of GRACE Stop-Gap and/or follow-on satellites to mitigate background signal aliasing errors.

In April 2010, a support letter was sent to Johnny Johannessen, NERSC, Isabelle Panet, Institut Géographique National, Thomas Gruber, and Roland Pail, for their "Earth System Mass Transport Mission (e.motion)" proposal to ESA's Earth Explorer Opportunity Mission under the EE-8-Call. Unfortunately the proposal was not selected to proceed into the next

phase. The e.motion team composed by a multi-disciplinary science team and an industrial team working in the area of satellite gravimetry, including members of the Satellite Mission Working Group, will continue to work together with the goal to define a next generation gravity field mission.

December 2010 – ongoing

In December 2010, Isabelle Panet and Roland Pail agree to be nominated as the new Co-Leads for the GGOS Satellite Missions Working Group.

In a Working Group meeting on April 2, 2011, the objectives and tasks of the SMWG for the upcoming period was extensively discussed, an Action Plan was drafted, and the charter has been reviewed. The list of members of the Working group is revised, and it is decided to invite also representatives of space agencies to become members in order to strengthen these interfaces.

Working Group on Outreach

Chair: G. Bianco (Italy)

The GGOS Working Group on Outreach and Education (WGOE) has been approved during the 11th meeting of the GGOS Steering Committee held on December 2010 in San Francisco, and modified during the GGOS Strategy Retreat held in February 2011 in Zurich. It is chaired by the GGOS Coordinating Office.

The WGOE activity in this initial period has been concentrated on a new edition of a brochure which shall describe GGOS' scope and duties according to the GGOS 2020 book as well as to the Terms of Reference and other strategic indications.

Working Group on ITRS Standardization

Chair: C. Boucher (France)

The Working group was established by the GGOS SC14 (San Francisco, December 2008) to investigate the interest in and feasibility of an ISO standardization document related to ITRS.

The WG Work Plan identified three major issues:

- to identify and get all useful information about existing standardization activities under the ISO umbrella which are somewhat linked to ITRS. One can also investigate, to some extent, standardization beyond ISO, either international bodies or even national agencies
- to define various options to get an ISO document referring to ITRS
- to report to GGOS

Survey of existing standards

Three types of standardization documents has been identified:

- documents of the ISO TC 211 "Geographical information-Geomatics" ISO TC 211
  - Geographical information. Spatial referencing by coordinates (ISO 19111)
- documents of the ISO TC 20 "Aircraft and Space Vehicles" ISO TC 20/SC 14
  - Space systems. Reference coordinate systems
  - Space systems. Orbit determination and estimation. Process for describing techniques
- documents related to the European INSPIRE directive

Options for a standard on ITRS

Various strategies were considered to bring the issue to ISO. The French standardization agency (AFNOR) performed a feasibility study. France was finally ready to start the process.

Content of the standard

The content of the standardization document related to ITRS was also considered. The proposed content includes general information on terminology, a definition of ITRS and an overview of the multiple realizations, including the primary one (ITRF), the regional densifications such as EUREF and the links with GNSS providers.

The WG submitted its final report to the 18th GGOS SC meeting in Vienna (2010)

Working Group on Contribution to Earth System Modelling

Chair: M. Thomas (Germany)

Purpose

In December 2010 the new Working Group on "Contributions to Earth System Modelling" has been established. The main purpose of the WG is to promote the development of a physically consistent numerical Earth system model that is simultaneously be applicable to all geodetic parameters, i.e., Earth rotation, gravity field and deformation, in order to allow homogeneous processing, interpretation, and prediction of these observables. Thus the WG is expected to finally contribute to a deeper understanding of dynamical and complex interacting processes in the Earth system integrally reflected in geodetic monitoring data.

Motivation

Traditionally, various independent models tailored to specific spatial and temporal scales and to specific dynamical processes in individual sub-systems of the Earth are applied in order to estimate particular contributions to observed variations of geodetic parameters. Although it is well known that the individual sub-systems are coupled via fluxes of mass, energy and momentum, these interactions are generally not adequate considered or even neglected, and the total amount of geophysical excitation is mostly described by a simple linear addition of the individual contributions. Another deficiency results from the fact that the various estimates are based on different standards and parameters and use diverse analysis strategies and formats.

Thus, in order to ensure physical consistency, in particular mass conservation, and to consider feedbacks a modular model approach with individual modules representing sub-systems or components interacting through boundary conditions is mandatory.

Goals

The long-term goal is the development of a modular numerical Earth system model for the homogeneous and physically consistent processing, interpretation and prediction of geodetic parameters. This implicates the following objectives:

- development of a physically consistent modular Earth system model considering the interaction and relationship between surface deformation, Earth rotation and gravity field variations as well as interactions and physical fluxes between relevant sub-systems;
- promotion of homogeneous processing of geodetic monitoring data (de-aliasing, reduction) by process modelling to improve analyses of geodetic parameter sets;
- contributions to the interpretation of geodetic parameters derived from different observation techniques by developing model based strategies to separate underlying physical processes;
- application of forward modelling and inversion methods in order to predict geodetic quantities and to invert geodetic observations for the underlying causative processes;
- development and implementation of coupling algorithms to ensure consistent interactions and physical fluxes among sub-systems;

– contributions to the integration of geodetic observations based on different techniques in order to provide a tool for validation and consistency tests of various geodetic products.

First steps

In the initial phase of the WG the activities are focussing on near-surface fluid dynamics which dominate short-term variations of geodetic parameters (Figure 7). For the near-surface modular system model approach a list of appropriate models for the representation of individual sub-systems is being generated and consistent standards, parameters, analysis strategies and formats for all components of the model approach are being defined. After a constitutive meeting of the WG, that is planned in 2011 and will be open to non-members also, relevant interactions among subsystems and appropriate parameterizations, in particular to represent the dynamic links between near-surface fluids and the "solid" Earth, shall be identified. The next step will be the development of strategies for the separation of temporal variations of Earth rotation, gravity and deformation into individual causative physical processes.

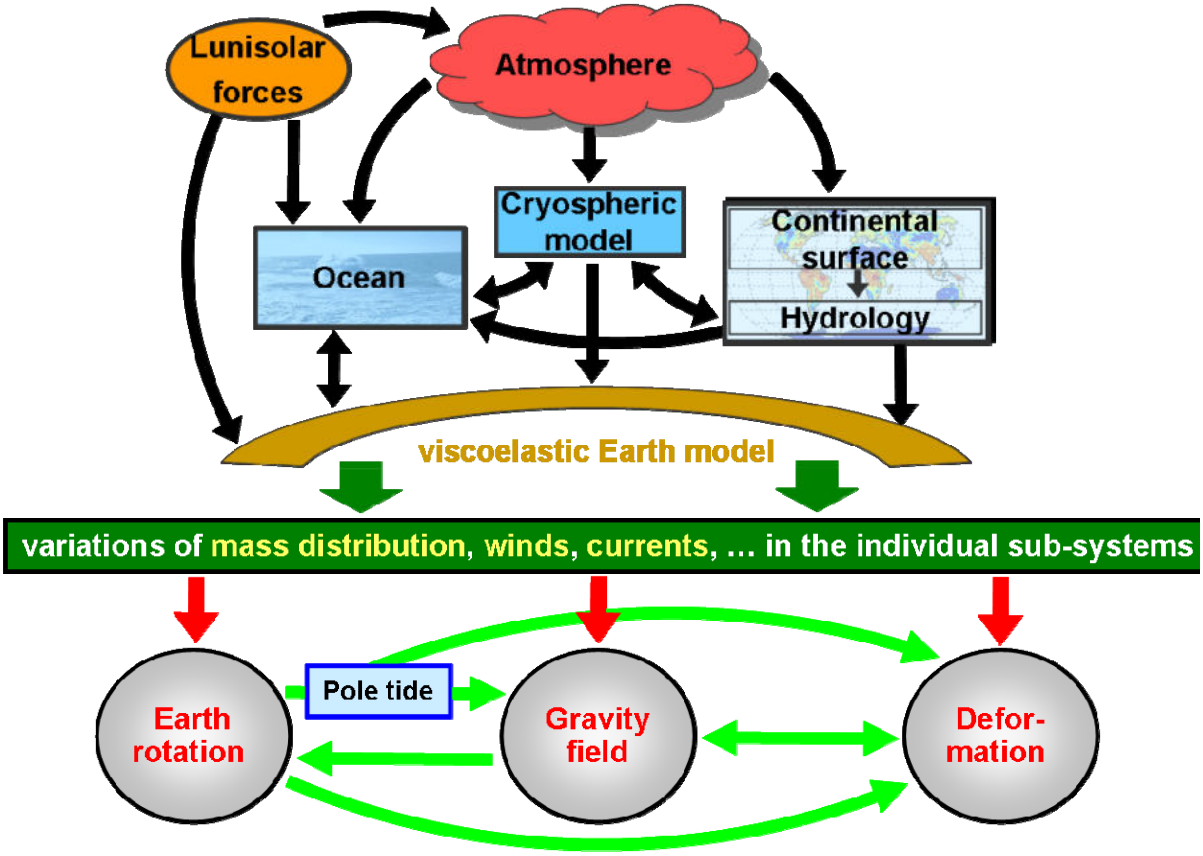

Figure 7: The modular 4d Earth system model approach for near-surface dynamics.

GGOS Coordinating Office

Chair: Giuseppe Bianco (Italy)

The GGOS Coordinating Office (CO) has been established in February, 2010, and is managed by the Italian Space Agency's Space Geodesy Centre located in Matera, Italy.

The main activities carried out by the GGOS CO have been:

- Enforcing the GGOS secretariat
- Managing the GGOS Executive Committee periodic teleconferences;
- Managing the GGOS correspondence

Another important activity done by the GGOS CO has been the new edition of the GGOS web page (www.ggos.org) which has been put on line on March, 2011 (see Figure 8). The web site will be mostly devoted to organization and documentation aspects.

Figure 8: GGOS web site home page

GGOS Portal

Chair: Bernd Richter (Germany)

The GGOS portal will provide a unique access point for all data, products and information relevant in the framework of GGOS to serve Earth science and applications. Basically, it will provide a platform for services to deliver data, to get and use these data for processing products and to get these products.

GGOS data are classified in three different levels:

- L0 level are all raw data,
- L1 level are all RINEX files (meta data, receiver, station), and
- L2 level and higher are the data and products that are provided by the IAG services) available on the GGOS portal through metadata files on the portal's data base (time series).

The GGOS Portal basically serves two different kinds of user: the data-providing user (IAG services and authorised non-IAG institutions) and the data-consuming user. Generally any registered user can upload data into the portal. Non-IAG institution's data and products will be included into the GGOS Portal only after having successfully passed a review process by the working group DIS and accepted finally by the GGOS EC. Further, each IAG and non-IAG service is required to specify their data by corresponding metadata.

The GGOS Portal will be used as a platform to exchange data and products presented topically ordered (natural hazards, science applications, geodetic applications, satellite missions, techniques and services).

The GGOS Portal is based on a service-oriented architecture. A prototype is ready and has been reviewed by the DIS WG and the GGOS EC (see Figure 9). The preliminary test version of the GGOS Portal web presentation can be found under http://observing-system-portal.bkg.bund.de. The GGOS web site and the GGOS portal web site cross linked for reference information and data respectively.

In general, the category "Topics" provides general information on a selected scientific topic . To provide the information the WG DIS and the GGOS EC has asked several individuals to provide detailed information to fill the various fields of interest.

The category "Discovery" will provide a search capability for data and products based on available metadata.

GGOS Portal Metadata

Three possibilities for the metadata description were discussed in the DIS WG:

- xml file template provided by the portal manager,
- a metadata block within the SINEX file, which includes not to distribute the SINEX files to the user,
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The GeoNetwork is embedded into the GGOS Portal web page as metadata editor (see Figure 10). The GeoNetwork (see http://geonetwork-opensource.org/) is based on the principles of Free and Open Source Software (FOSS) and International and Open Standards for services and protocols (a.o. from ISO/TC211 and OGC). The use in numerous Spatial Data Infrastructure initiatives across the world guaranteed the long-term support. A range of standards is implemented like metadata standards (ISO19115/ISO19119/ISO19110 following ISO19139, FGDC and Dublin Core), Catalog interfaces (OGC-CSW2.0.2 ISO profile client and server, OAI-PMH client and server, GeoRSS server, GEO OpenSearch server, WebDAV harvesting, GeoNetwork to GeoNetwork harvesting support) and Map Services interfaces (OGC-WMS, WFS, WCS, KML and others) through the embedded GeoServer map server.

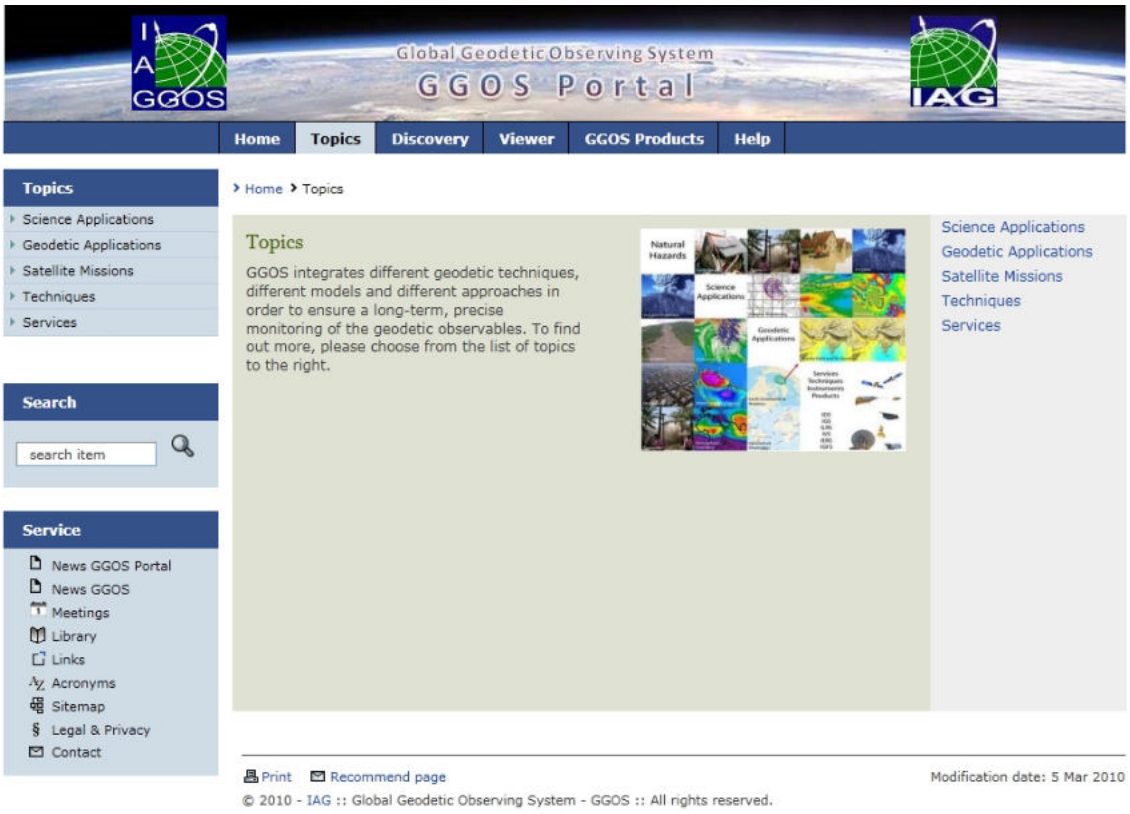

Figure 9: GGOS Portal (screen shot main page Topics)

Figure 10: GeoNetwork page "Advanced search" presently under test not yet implemented

The available ISO metadata catalogue has been discussed within the DIS WG and tailored to the necessary geodetic applications. The used fields to describe the individual data are specified in the document presented at the GGOS / IERS UAW workshop in Monterey, Ca.

http://www.iers.org/nn_10902/IERS/EN/Organization/Workshops/Workshop2007MontereyProgramme.html?__nnn=true#doc74712bodyText4 see Sess. 6

"UAW_PosPap_Session_6_GGOS_Portal_and Metadata_Flow_Annexes_1.pdf".

GGOS Science Panel

Chair: Richard Gross (USA)

Members

Jonathan Bamber (UK)
Anny Cazenave (France)
Athanasios Dermanis (Greece)
Andrea Donnellan (USA)
Roger Haagmans (The Netherlands)
Paul Poli (UK)
Matt Rodell (USA)
Reiner Rummel (Germany)
Seth Stein (USA)
John Wahr (USA)
Victor Zlotnicki (USA)

The GGOS Science Panel is a multi-disciplinary group of experts representing the geodetic and relevant geophysical communities that provides scientific advice to GGOS in order to help focus and prioritize its scientific goals. The Chair of the Science Panel is a member of the GGOS Steering Committee and all members of the Science Panel are invited to participate in meetings of the GGOS Steering Committee. The Chair of the Science Panel is also a guest of the GGOS Executive Committee and is invited to participate in its meetings and tele-conferences. This close working relationship between the Science Panel and the governance entities of GGOS ensures that the scientific expertise and advice required by GGOS is readily available.

Activities

Besides participating in GGOS Steering and Executive Committee Meetings, the Science Panel has been actively promoting the goals of GGOS by helping to organize relevant sessions at major scientific conferences. GGOS-related sessions have been organized each year during 2006–2011 at the General Assemblies of the European Geosciences Union and each year during 2007–2010 at the Fall Meetings of the American Geophysical Union (AGU). In addition, a GGOS session was organized at the 2009 Scientific Assembly of the IAG. And plans have been made to organize sessions relevant to GGOS at the XXV General Assembly of the IUGG that will be held during 28 June – 7 July 2011 in Melbourne Australia and at the 2011 Fall Meeting of the AGU that will be held during 5–9 December 2011 in San Francisco, Calif.

In addition to helping organize sessions at scientific conferences, the GGOS Science Panel also convenes topical workshops in order to foster discussion about the geodetic observations and infrastructure required by different scientific disciplines. Two such workshops were convened during 2007–2011:

Understanding Glacial Isostatic Adjustment: A Joint DynaQlim/GGOS Workshop

The Global Geodetic Observing System of the International Association of Geodesy and the International Lithosphere Program Regional Co-ordination Committee DynaQlim jointly organized a workshop on "Understanding Glacial Isostatic Adjustment" that attracted 36 international participants to Espoo, Finland during June 23-26, 2009. The objectives of this workshop were to: (1) review the current state of the science in modelling glacial isostatic adjustment, (2) review the use of geodetic measurements to both constrain and to test GIA models, (3) identify obstacles to improving GIA models, and (4) identify the improvements to

the global geodetic observing system that are required to advance our understanding of glacial isostatic adjustment. Workshop participants made a number of recommendations regarding geodetic observations and infrastructure, including those summarized below.

Isolating the GIA signal in geodetic observations is an important prerequisite to advancing our understanding of the GIA process. Workshop participants identified gravity observations from GRACE as being key in this regard because of its ability to use the differing fingerprints of GIA and present-day ice mass change to aid in their separation. The continued acquisition of time variable gravity observations from space was strongly recommended by the workshop participants.

The BIFROST network in Fennoscandia has demonstrated the importance of regional networks of GNSS receivers, surface gravity instruments, and seismometers (not necessarily collocated) for understanding the GIA process. Such networks should be established in other areas of uplift. Measurements from such high-latitude networks can also be used to improve the terrestrial reference frame (TRF), which is currently stable to only about 1 mm/yr. Since the GIA-induced motion of the geocentre (the offset of the centre-of-mass of the Earth from the centre of the network of observing stations) is estimated to be between 0.1 mm/yr and 1 mm/yr, the stability of the TRF needs to be improved by at least an order of magnitude so that estimates of this small signal are not corrupted by errors in the reference frame within which the measurements are being taken.

A summary of the workshop was published in *Eos, Transactions of the American Geophysical Union* [Gross, R., and M. Poutanen, Geodetic observations of glacial isostatic adjustment, *Eos Trans. AGU*, *90*(41), 365, 2009] and the proceedings of the workshop will be published as a special issue of the *Journal of Physics and Chemistry of the Earth*.

Observing and Understanding Earth Rotation: A Joint GGOS/IAU Science Workshop

The Global Geodetic Observing System of the International Association of Geodesy and Commission 19 (Rotation of the Earth) of the International Astronomical Union jointly organized a workshop on "Observing and Understanding Earth Rotation" that attracted 90 participants from 12 countries to Shanghai, China during October 25-28, 2010. The objectives of this workshop were to: (1) assess our current ability to observe the Earth's time varying rotation, (2) assess our current understanding of the causes of the observed variations, (3) assess the consistency of Earth rotation observations with global gravity and shape observations, (4) explore methods of combining Earth rotation, gravity, and shape observations to gain greater understanding of the mass load acting on the surface of the solid Earth, and (5) identify improvements in the global geodetic observing system needed to further our understanding of the Earth's variable rotation.

Measurements of the Earth's time varying rotation have been traditionally provided by optical astrometry and the space-geodetic techniques of satellite and lunar laser ranging (SLR and LLR), very long baseline interferometry (VLBI), global navigation satellite systems (GNSS) like the global positioning system (GPS), and Doppler orbitography and radio positioning integrated by satellite (DORIS). However, the launch of the GRACE twin gravity satellites in March 2002 and the densification of the global GNSS ground receiver network afford new opportunities for studying the Earth's rotation. GRACE is directly observing the effect of mass redistribution on the Earth's rotation, and the global network of GNSS ground receivers can be used to infer changes in the load acting on the Earth's surface and its effect on the Earth's rotation from observations of changes in the Earth's shape.

In the future, greater understanding of the processes causing not only the Earth's rotation but also its gravity and shape to change will be obtained by integrating Earth rotation, gravity, and shape measurements into a global geodetic observing system. This integration is one of the essential goals of GGOS and this workshop took us one step closer to that goal.

A summary of the workshop was published in *Eos, Transactions of the American Geophysical Union* [Gross, R., H. Schuh, and C.-L. Huang, Spin, wobble, and nutation, *Eos Trans. AGU*, *92*(4), 31, 2011] and the proceedings of the workshop will be published as a special issue of the *Journal of Geodynamics*. This special issue will consist not only of papers presented at the workshop but will also include other contributions on this topic that are submitted in response to an open call for papers.

GGOS Themes

Chairs: Michael Sideris (Canada), Tim Dixon (USA) and C.K. Shum (USA)

Overview

The idea to establish GGOS themes goes back to the Workshop on Future Satellite Gravity Missions in Graz in September 2009, where Reiner Rummel presented his thoughts about Thematic (Geodetic) Observing Systems. Because of the complexity of the Earth system it makes sense, instead of working on the entire complex Earth system at once, to first consider Thematic (Geodetic) Observing Systems (and Models) in order to be able:

- to cope with the complexity of the Earth system
- to work on an integrated but limited / manageable part of the Earth system
- to get an independent control
- to generate suitable integrated GGOS products

Examples of such thematic geodetic observing systems are the themes „Ice Mass Balance", „Continental Water Balance" or „Sea Level Change" (see Figure 11).

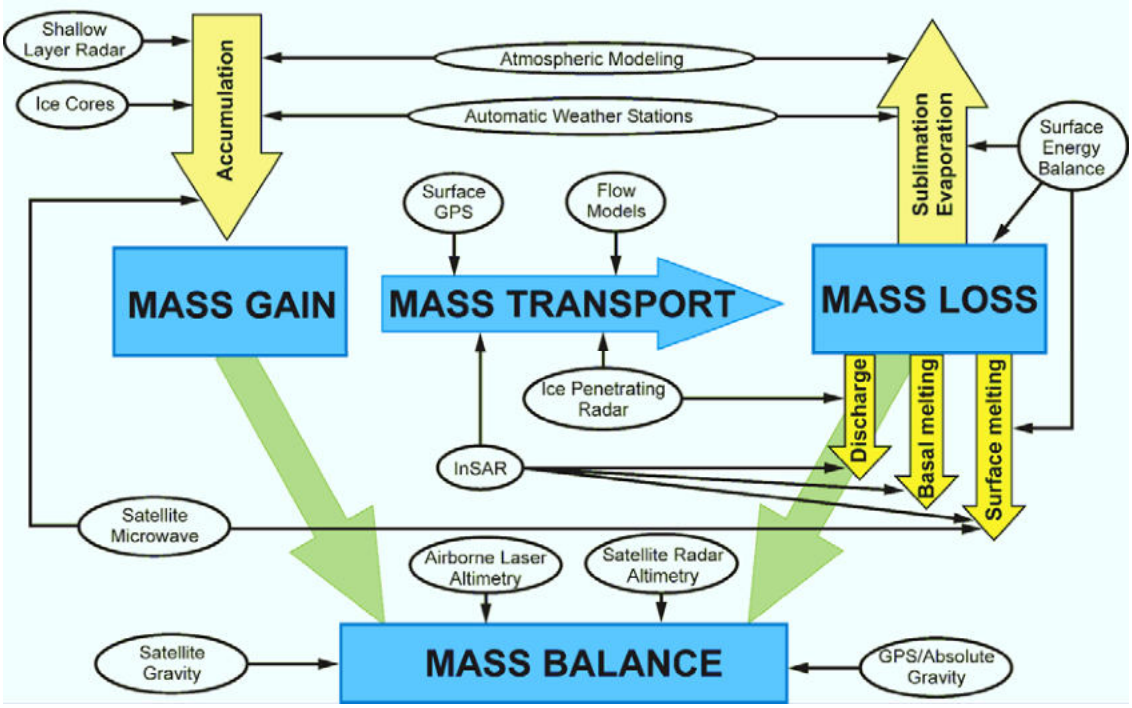

Figure 11: Example of a Thematic Geodetic Observing System on "Ice Mass Balance" (Thomas, EOS, 2001)

In a second and later step the Thematic (Geodetic) Observing Systems would then be connected and linked to the Global (Geodetic) Observing System:

- as partial systems of global Earth system studies
- for Earth rotation studies on global mass balance, where mass and motion have to be combined
- for consistency and quality checks between the Thematic (Geodetic) Observing Systems

In preparation for the GGOS Retreat in February 2010 in Miami, three thematic (geodetic) observing systems or integrated products were selected (as a start):

- Theme 1: Global Unified Height System (Chairs: M. Sideris, J. Ihde)
- Theme 2: Geohazards (global Earth surface deformations and strain rates for geohazards assessment and disaster prevention) (Chairs: T. Dixon, R. Gross)
- Theme 3: Understanding and Forecasting Sea-Level Rise and Variability (Chairs: C.K. Shum., Phil Woodworth)

The progress made since the GGOS Retreat 2010 in Miami is described in the following sections of this report.

GGOS Theme 1: Unified Global Height System

Chairs: Michael Sideris, Johannes Ihde

The Inter-Commission Project 1.2: Vertical Reference Frames (ICP1.2) is a common project of IAG Commission 1 and 2 (http://whs.dgfi.badw.de). From beginning of 2010 the activities of ICP1.2 were integrated in GGOS as Theme 1.

The definition and realization of a World Height System (WHS) is a fundamental requirement of GGOS (Global Geodetic Observing System). In the same way as the ITRS/ITRF provides a high precision geometrical reference frame, the WHS shall provide the corresponding high precision physical reference frame for studying the system Earth.

The results of the work of the ICP1.2 in the first term 2003 – 2007 are documented in Conventions for the Definition and Realization of a Conventional Vertical Reference System (CVRS), Ihde et al. 2007. The main objective for the second term 2007 – 2011 is the initiation of a pilot project for a WHS realization (WHS-PP).

In July 2010 the description of the WHS Pilot Project with a call for information about planned contributions was send out. The deadline for final contributions Survey of WHS-PP results is May 2011 and the final report will be given at IAG General Assembly 2011.

The four WHS-PP Work Items are:

1. *Analysis centres for determining and monitoring the relationship between a conventional W0 and the potential of the Earth gravity field level surface closely coinciding with the mean sea surface*
2. *Regional processing centres and global combination centres for GNSS/levelling stations with coordinate time series in the current ITRF linked to TIGA stations and geo-potential numbers referred to the RHS at defined epochs*
3. *Investigations on the accuracy of computing point values Wp of the gravity potential by means of high resolution gravity field models and regional densifications of gravity data*
4. *Operative determination of physical WHS heights in regions with a weak geodetic infrastructure including and development of an information system (registry) providing relevant data*

At the end of the second term of ICP1.2 and after the work of the various WIs is completed, the ICP1.2 will prepare a final report and recommendations on how to best realize the WHS (including all relevant issues such as the computation and adoption of a "best" W_0 value, an optimal global geoid surface, etc.) This report will be presented at the IAG General Assembly in Melbourne.

In the future, the work of ICP should continue in the form of a GGOS Integrated Product (i.e., Theme 1) for the establishment and maintenance of a WHS. The International Gravity Field Service (IGFS) should take the leading role there and report directly to GGOS. GGOS has to clarify inconsistencies in the numerical parameters for integrated geodetic applications. Conventions for the definition and realization of the parameters of the MSSL have also to be agreed.

GGOS Theme 2: Geohazards

Chairs: Tim Dixon, Richard Gross

Geodetic measurements have a fundamental role to play in the understanding and mitigation of many natural hazards. Most hazard assessment requires comparing measurements before and after some event in order to detect a change. Examples include volcano monitoring, coastal subsidence associated with flood hazards, subsidence associated with tunnel construction or excess groundwater/oil extraction, and earthquake co-seismic offsets and post-seismic activity. While GNSS measurements have been very successfully used to study these and other geohazards, Synthetic Aperture Radar (SAR) is being increasingly used because of its superior spatial resolution. But whether using GNSS or SAR measurements, the successful detection of a change on the ground from space requires accurate reference frames, satellite orbits, atmospheric models, etc. The objective of GGOS Theme 2 on Geohazards is to improve the effectiveness of the geodetic community in geohazard identification, assessment, prioritization, prediction, warning, and research.

Much progress has been made in the past decade on improving change detection on the ground from space but more progress is needed. In particular, continued refinement of the accuracy and stability of the ITRF, improved ultra-rapid GNSS orbits including lower refresh rates, better clock estimates for precise point positioning, better atmospheric models, lower latency ultra-precise SAR orbits, and better regional coverage of InSAR images are all needed. GGOS can play a very effective role in advocating for the improvement in geodetic infrastructure and data analysis needed for geohazards applications, not only by itself but also by working with other groups such as the GEO Supersites Initiative.

The Geohazard Supersites is a GEO initiative to better understand the geophysical processes causing geohazards <http://supersites.earthobservations.org>. It consists of a global partnership of scientists and satellite and *in situ* data providers (multi-sensor InSAR, seismic, and GNSS) having the goal of supporting national authorities and policy makers in risk assessment and mitigation strategies. A closer working relationship between GGOS and the GEO Supersites Initiative would aid Theme 2 in meeting its objective.

GGOS Theme 3: Understanding and Forecasting Sea-Level Rise and Variability

Chairs: C.K. Shum, Phil Woodworth

This activity was initiated primarily as a demonstration Theme to show the value of geodesy, and GGOS in particular, to a high-profile area of science and applications. Sea level is anyway an important geodetic quantity (traditionally being the basis of the geodetic datums of many countries), but it is also of great scientific and public interest, especially with regard to potential sea-level rise, local land motion, and flooding of coastal environments and infrastructures.

The Theme is managed by a group of scientists comprising Philip Woodworth, C.K. Shum, Tilo Schöne, Mark Tamisiea and Per Knudsen. At its outset, it set itself three broad topics of activity:

1. Identification of the requirements for a proper understanding of global and regional/local sea-level rise and variability, and the associated land motion, especially in so far as they relate to geodetic monitoring provided by the GGOS infrastructure, and their current links to external organizations (e.g. GEO).
2. Identification of the organizations or individuals who can take forward each requirement, or act as points of contact for each requirement where they are primarily the responsibility of bodies not related to GGOS.
3. Identification of a preliminary set of practical (as opposed to scientific) pilot projects, which will demonstrate the viability, and the importance of geodetic measurements to mitigation of sea-level rise at a local or regional level. This identification will be followed by construction of proposals for pilot projects and their undertaking.

These topics are described in detail in the Theme Action Plan (latest version dated 6 April 2011). Although some thoughts are expressed in the Action Plan on how to take forward the first two topics, in practice progress has been made only in organizing the third topic.

This topic is based on a proposal by H-P Plag two years ago. It is concerned with the forecasting of sea-level change over various timescales, focussing on the sea-level rise to be expected in the medium term (e.g. less than 30 years) at major cities and population centres for input to coastal defence planning. Such projects would be of considerably greater utility to planners than the 2100 projections provided by IPCC Assessments, for example, a timescale of 30 years being long enough for many civil engineering schemes to be undertaken.

Our feeling is that such demonstration activities could benefit from previous experience with projects such as the Thames Estuary 2100 study for London and similar studies in the Netherlands, Denmark, US Pacific and Atlantic coasts etc. Potential areas for further study might include Manila, Bangkok, Shanghai, Djakarta, Lagos and other large Asian and African cities for which submergence (natural or anthropogenic) and/or storm surge risk of flooding are major considerations, or countries such as Bangladesh or Egypt which include large deltas where high rates of sea level rise are a natural phenomenon to be lived with. (A relevant reference here is to the 'Cities at Risk' international activities, start.org/programs/cities-at-risk.)

Our plan is to issue a Call for Proposed Projects under this action by the middle of 2011, which will require (geodetically) integrated approaches to studies of sea level change on 30 year (forecast) timescales. The projects will be publicised through GGOS using a standard

format and will be open to both, existing or past projects as well as to new ones, the latter benefitting potentially from support from GGOS in their search for funding. The value of including existing or past projects is that they can be used immediately to demonstrate the value of the action.

GGOS in the Group on Earth Observation (GEO)

Representative to the Plenary: Markus Rothacher (delegation head), Ruth Neilan, Susanna Zerbini (Science and Technology Committee), Bernd Richter (Architecture and Data Committee)

Overview

GGOS, representing the IAG within GEO, has been actively involved in GEO since the IAG became a participating organization of GEO in 2005. The main contributions made by the GGOS representatives are

- GGOS tasks within the GEO Work Plan 2007-2011
- Participation in GEO Committees and Working Groups
- Participation in the GEO Plenary Meetings and Ministerial Summits

This work is especially important, because it makes GGOS much more visible to the outside world and leads to contacts to all major international organizations in the field of Global Erath Observation.

Main tasks within GEO Work Plan 2007-2011

Based on an initiative of H.P. Plag GGOS is presently contributing with two major tasks to the GEO Work Plan 2007-2011 and is involved in a third:

DA-09-02: Data Integration and Analysis. **Subtask DA-09-02c**: Global Geodetic Reference Frames. Task leader from IAG/GGOS is Zuheir Altamimi. Before March 2010 it was H.P. Plag.

AR-09-03: Advocating for Sustained Observing Systems. **Subtask AR-09-03e**: Global Geodetic Observing System (GGOS). Task leader Mike. Pearlman.

ST-09-02: Promoting Awareness and Benefits of GEO in the Science and Technology Community. Susanna Zerbini is the representative of GGOS here.

These tasks will also be continued in the GEO Work Plan 2011-2015. More details may be found below.

GEO Committees and Working Groups

The participation of GGOS in a number of GEO Committees and Working Groups from 2007-2011 is summarized in Table 5. Major efforts were done in the GEO Science and Technology Committee , the GEO Architecture and Data Committee and the GEO User Interface Committee. More details are given below. GGOS was also represented in the GEO Working Group on Tsunami during its rather short existence.

Table 5: Representatives of GGOS in GEO Committees and Working Groups

Period	GEO Committee / WG	Representatives
2007-2010	GEO Science and Technology Committee	S. Zerbini, M. Pearlman, M. Rothacher
2007-2010	GEO Architecture and Data Committee	B. Richter, C. Noll, R. Neilan, H.P. Plag
2007-2010	GEO User Interface Committee	H.-P. Plag, C.K. Shum, C. Boucher
2007-2010	GEO Capacity Building and Outreach Committee	C. Rizos, H. Drewes, L. Combrinck
2007-2010	GEO WG on Tsunami Activities	H.-P. Plag, T. Schöne
2010-…	GEO Science and Technology Committee	S. Zerbini, R. Gross
2010-…	GEO Architecture and Data Committee	B. Richter, C. Noll
2010-…	GEO User Interface Committee	J. Park, C. Rizos
2010-…	GEO Capacity Building and Outreach Committee	M. Pearlman, R. Neilan, L. Combrinck

GEO Plenaries and Ministerial Summits

During the period from 2007 to 2011 the GGOS representatives participated in all the GEO Plenary and Ministerial Summits. Table 6 lists these GEO events and the activities of GGOS during these events. The main emphasis was on getting contacts and connections to UN organizations and other international bodies and to promote GGOS within GEO. A GGOS booth was realized and a considerable amount of outreach material (leaflets, posters, brochures, 1-page stories, …) and used at many of the GEO Plenaries.

Table 6: GEO Plenary Meetings and Ministerial Summits from 2007-2011

GEO Event	GGOS Activities	GGOS Participants
GEO Plenary IV and Ministerial Summit, Cape Town, South Africa, Nov. 2007	GGOS booth set up with the help of GFZ and R. Wonnacott. Many contacts to international organizations to promote GGOS	M. Rothacher, R. Neilan, H.P. Plag
GEO Plenary V, Bucharest, Romania, Nov. 2008	GGOS booth set up with the help of GFZ and R. Wonnacott. Many important contacts to UN organizations	M. Rothacher, H.P. Plag
GEO Plenary VI, Washington DC, USA, Nov. 2009	GGOS booth, GGOS outreach material, flyers, videos; contacts to international organizations	M. Rothacher, H.P. Plag, R. Neilan, M. Pearlman, S. Zerbini
GEO Plenary VII and Ministerial Summit, Beijing, China, Nov. 2010	Official statement of GGOS in Min.Summit, GGOS booth, contacts with many international organizations	M. Rothacher, R. Neilan, C. Rizos, S. Zerbini

GEO Science and Technology Committee

Main Representative: Susanna Zerbini

The GEO Science and Technology Committee (STC) was established in 2006 and since then met 16 times in different locations all around the world. Susanna Zerbini, representing IAG/GGOS, participated to most of these meetings and provided an active contribution to the development of the STC activities. Detailed information on the meeting outcomes is available at http://www.earthobservations.org/com_stc_me.shtml.

The STC engages the scientific and technological communities in the development, implementation and use of a sustained Global Earth Observation System of Systems (GEOSS) in order to ensure that GEO has access to sound scientific and technological advice. Objectives of the STC are:

- Enable GEO to make decisions on best available and sound scientific and technological advice, through the solicitation of input from a broad, trans-disciplinary scientific and technological community
- Ensure scientific and technological integrity and soundness of GEO Annual Work Plans.
- Monitor and review output and deliverables of GEO Annual Work Plans.
- In collaboration with GEO Members and participating organizations, and through transparent processes, identify individual experts and groups to participate in GEO working groups.
- Facilitate linkages and partnership with major relevant international research programs as well as organizations willing to contribute to GEO activities.

During the reporting period, the STC was engaged in several different activities.

The Role of Science and Technology in GEOSS

A document was prepared which describes the "Role of Science and Technology in GEOSS". It was published in 2008 and it can be downloaded from http://ec.europa.eu/research/ environment/pdf/geoss.pdf. This document describes the role of science and technology in advancing the GEOSS through the GEO 2007-2009 Work Plan. The STC is working to strengthen this role by encouraging the wider scientific and technology community to participate as contributors to and benefactors of a sustained GEOSS.

STC is responsible for and/or overlooking several GEO tasks. IAG/GGOS contributes to one of them: ST-09-02.

TASK-ST-09-02 Title: Promoting Awareness and Benefits of GEO in the Science and Technology Community.

The task definition is: Promoting awareness and benefits of GEOSS in the scientific and technological communities in order to engage the research community in GEO and GEOSS with the goal to achieve breakthroughs in the understanding of the Earth's changing environment and global integrated Earth system. The scientific community should collaborate within GEO to address interactions between the components of the global integrated Earth system, and connect natural and socioeconomic sciences.

Activities include: (i) form links with major scientific research enterprises in each societal benefit area; (ii) actively encourage relevant scientists and technical experts to contribute to GEOSS in a truly participatory way; (iii) reach out to the world's diverse scientific and technological communities and make GEOSS more visible and attractive to them; (iv) contact universities and laboratories to involve them in GEOSS activities; and (v) organize a GEO presence at major symposia and other meetings, for example through plenary presentations or side events.

IAG/GGOS is actively engaged in several of the above mentioned activities, in particular, as regards activities from (ii) to (v).

Following the GEO-V Plenary (November 2008), the STC took action to develop a STC roadmap. This roadmap was finalized in early 2009 and subsequently approved by the STC. It can be downloaded from http://www.earthobservations.org/documents/committees/stc/stc_roadmap_20091202.pdf.

The status of the roadmap is being checked during the STC meetings

Roadmap

This roadmap identifies and motivates the path that the STC of the GEO has decided to pursue to achieve its objectives. It primarily addresses the Committees of GEO, its Task Teams, working groups and Communities of Practise. It also addresses the Science and Technology (S&T) communities within the scope of the Societal Benefit Areas of the GEOSS and the S&T communities needed to build, deploy, access and sustain the GEOSS.

Gap Analysis Strategy

The GEO Executive Committee (ExCom), during its 19th meeting, recognized that the GEO community needed an overall strategy for analysis of observational and structural gaps. This lead to an Action (19.11) which involves the STC, the Monitoring and Evaluation Working Group and other interested members of the GEO Community to draft an initial outline of a process that can eventually lead to a coherent overall mechanism being put in place for required GEO/GEOSS gap analyses.

GEO Architecture and Data Committee

Main Representative: Bernd Richter

The Architecture and Data Committee (ADC) supports GEO in all architecture and data management aspects of the design, coordination, and implementation of the Global Earth Observation System of Systems (GEOSS) for comprehensive, coordinated, and sustained Earth observations.

During the time span the GEOSS Common Infrastructure had been implemented. Starting with three Web-Portals and three clearinghouses benchmark tests and reviews lead to one Web-Portal hosted by ESA and one clearinghouse set up by USGS. Also necessary recommendations for standards and interoperability in GEOSS have been developed as well as the data sharing principles.

GGOS contributed to the GEO work plan by two tasks supporting an integrated GEOSS under the guidance of the Architecture and Data Committee.

AR-09-03: Advocating for Sustained Observing Systems / Subtask: e) Global Geodetic Observing System (GGOS)

This sub-task is led by IAG (mpearlman@cfa.harvard.edu)

Promote the further development of sustained infrastructure needed to satisfy the long-term (10-20 years) requirements for the reference frames and the monitoring of global change signals. GGOS provides observations of variations in Earth shape, gravity field and rotation, which are fundamental for monitoring of climate and global change. GGOS observations contribute to at least seven of the SBAs. Moreover, with the global geodetic reference frames (International Terrestrial Reference Frame (ITRF) and International Celestial Reference Frame), GGOS provide the foundation for most Earth observations. Among other components, geodetic monitoring of global change crucially depends on globally sustained geodetic ground networks.

DA-09-02: Data Integration and Analysis / Subtask: c) Global Geodetic Reference Frames

This sub-task is led by IAG (zuheir.altamimi@ensg.ign.fr)

Ensure the availability of accurate, homogeneous, long-term, stable, global geodetic reference frames as a mandatory framework and the metrological basis for Earth observation. Identify steps towards such consistent high-accuracy global geodetic reference frames for Earth observation and the observing systems contributing to GEOSS. Promote the use of common or interoperable reference frames within GEOSS.

GEO User Interface Committee

A very substantial amount of work in the GEO User Interface Committee (UIC) (as well as in other GEO committees) was done by Hans-Peter Plag. He was the main representative of GGOS in this committee until March 2010.

GEO Capacity Building Committee

Since March 2010 GGOS is also involved in the GEO Capacity Building Committee. The main representatives are Mike Pearlman and Ruth Neilan.