Global Geodetic Observing System (GGOS)

http://www.ggos.org

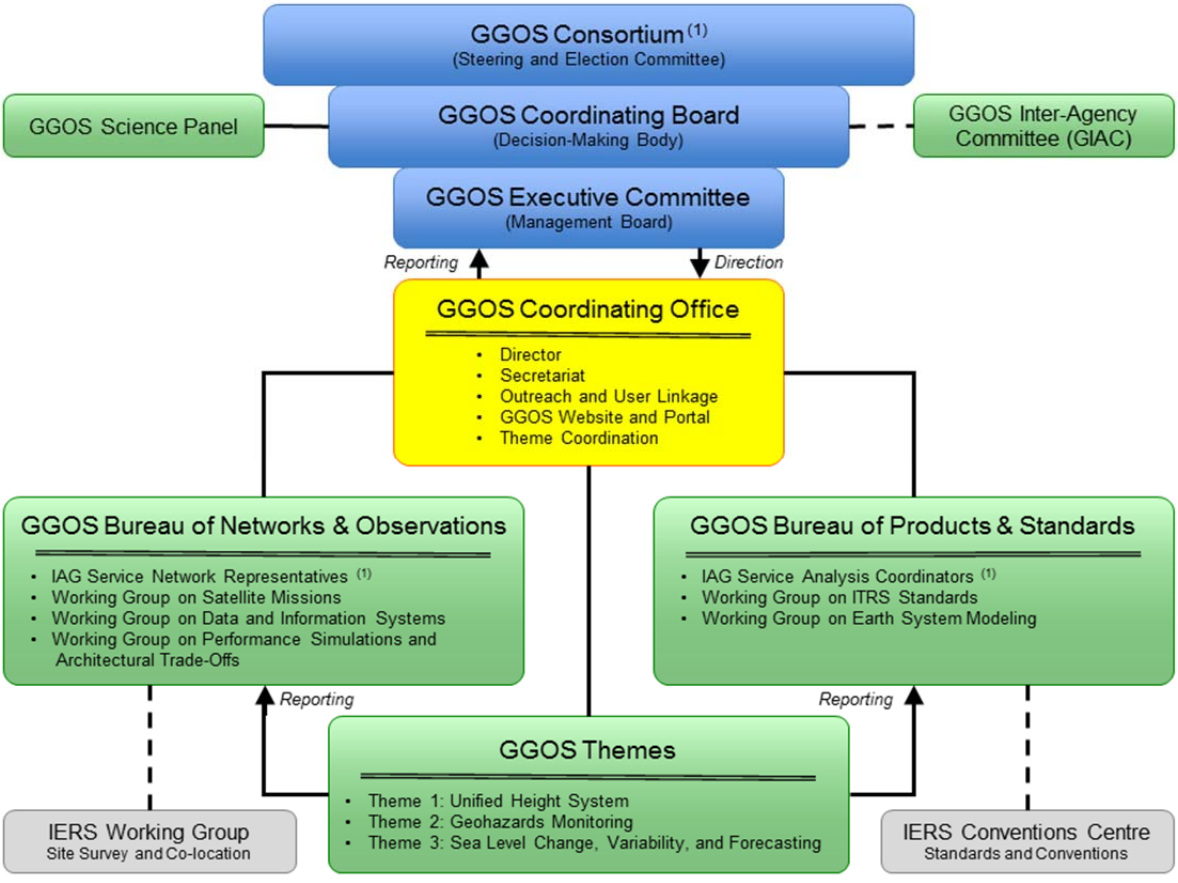
Chair: *Hansjörg Kutterer (Germany)*
Vice Chair: *Ruth Neilan (USA)*

As the observing system of the IAG, GGOS serves a unique and critically important combination of roles centering upon advocacy, integration, and international relations. GGOS also promotes high-level outcomes, such as the realization of the International Terrestrial Reference Frame through a variety of internal and external channels.

GGOS Structure and Overview

Structural Streamlining

In order to make optimal use of the GGOS structure introduced in 2011, streamlining efforts took place from late 2013 to early 2015, resulting in the following organizational structure:



(1) GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

In this effort, the role of the Coordinating Office (CO) has been enhanced in order to best serve the Executive committee, Coordinating Board, and Consortium. The CO serves as a centralized administrative and organizational entity, and interacts with the Bureaus and Focus Areas (formerly Themes) for day-to-day organizational matters.

Working groups have been organized under one of the two bureaus, in order to make most efficient use of respective efforts. The Bureau of Standards and Conventions was renamed to the Bureau of Products and Standards, in order to better reflect its work as a bureau as well as its associated working groups. The Bureau of Networks and Communications was renamed to the Bureau of Networks and Observations, in order to better represent its work and the working groups within its authority.

Strategic Planning and Update of Terms of Reference

Starting with the 2013 Strategic Plan, GGOS has been making strides toward a goal, objective, and outcome-oriented strategic planning and implementation process. Subsequent yearly Strategic Implementation Plans have been drafted by the Science Panel, Coordinating Board, Coordinating Office, the Bureau of Networks and Observations, and the Bureau of Products and Standards. Each of the aforementioned components will use these plans to align their efforts with that of the overall Strategic Plan, and ensure progress toward the four GGOS goals.

In order to reflect the structural streamlining and strategic direction, the GGOS Terms of Reference have been updated in 2015.

GGOS Consortium

The GGOS Consortium is the collective voice for all GGOS matters. The elements of GGOS have the flexibility to determine and designate two representatives to the GGOS Consortium as each (Service, Commission, Inter-Commission Committee, or other entity) decides. The Consortium membership (see Table 1) is comprised of the Chairs of Services and the Directors of the Service's central offices or Central Bureaus; Presidents and Vice-Presidents of IAG Commissions, Inter-Commission Committees, and other entities essential to GGOS as determined by the Consortium. The GGOS Consortium is the nominating and electing body of elected positions on the GGOS Coordinating Board, with the Chair of GGOS acting as the Chair of the GGOS Consortium.

Table 1: Members of the GGOS Consortium (as of April 2015)

Services	Name	Title
GGOS	Hansjörg Kutterer	GGOS Chair
Int'l Gravimetric Bureau (BGI)	Sylvain Bonvalot	Director
Bureau International des Poids et Mesures (BIPM) - Time Section	Elisa Felicitas Arias	Director
International Altimetry Services (IAS)	Wolfgang Bosch Cheinway Hwang	Chair
IAG Bibliographic Service (IBS)	Annekathrin Michlenz	Chair
International Center for Earth Tides (ICET)	Jean-Pierre Barriot	Chair
International Centre for Global Earth Models (ICGEM)	Franz Barthelmes	Director
International Digital Elevation Model Service (IDEMS)	Philippa Berry R.G. Smith	Director
International Doris Service (IDS)	Laurent Soudarin Pascal Willis	Director Chair
International Earth Rotation and Reference Systems Service (IERS)	Daniela Thaller Thomas Herring	Director of the Central Bureau Analysis Coordinator
International Service for Geoid (ISG)	Mirko Reguzzoni Giovanna Sona	President Director
International Gravity Field Service (IGFS)	Riccardo Barzaghi Steve Kenyon	Chair Director of the Central Bureau
International GNSS Service (IGS)	Ruth Neilan Gary Johnston	Director Chair
The International Laser Ranging Service (ILRS)	Giuseppe Bianco Erricos Pavlis	Chair of Governing Board Analysis Coordinator
International VLBI Service for Geodesy and Astrometry (IVS)	Axel Nothnagel Dirk Behrend	Chair Coordinating Center Director
Permanent Service for Mean Seal Level (PSMSL)	Lesley J. Rickards Mark Tamisiea	Director

The Consortium meets annually, with the most recent meetings taking place in December of 2013 and 2014, in San Francisco, USA.

GGOS Coordinating Board

The GGOS Coordinating Board sets the strategic direction of GGOS in consultation with the GGOS Consortium and monitors the implementation of the adopted strategic plan. As such, the Coordinating Board monitors the GGOS Coordinating Office, which is tasked to manage and coordinate day-to-day activities leading to the fulfillment of strategic objectives. The Co-ordinating Board reports overall progress to the GGOS Consortium.

Table 2: Members of the GGOS Coordinating Board (as of April 2015)

Title	Name	Voting Rights
Voting Coordinating Board Members		
GGOS Chair	Hansjörg Kutterer	1 (voting)
Vice-Chair	Ruth Neilan	1 (voting)
Chair of GGOS Science Panel	Richard Gross	1 (ex-officio, voting)
Director of Coordinating Office	Giuseppe Bianco *(through April 2015)*	1 (ex-officio, voting)
Directors of GGOS Bureaus	Michael Pearlman Detlef Angermann	2 (ex-officio, voting)
IAG President (or designated representative)	Chris Rizos	1 (ex-officio, voting)
Service Representatives	Pascal Willis Ruth Neilan Erricos Pavlis Thomas Herring	4 (elected by the Consortium, voting)
IAG Commissions Representatives	Srinivas Bettadpur Tonie van Dam	2 (elected by the Consortium, voting)
Members-at-Large	Maria Cristina Pacino Yoichi Fukuda Yamin Dang	3 (elected by the Consortium, voting)
Non-voting Coordinating Board Members		
Chairs of GGOS Working Groups	Roland Pail Bernd Richter Maik Thomas Giuseppe Bianco Daniela Thaller	
Theme Leads	Michael G. Sideris Tim Dixon Tilo Schoene	
GGOS Portal Manager	Bernd Richter	
Immediate Past Chair of the CB	Markus Rothacher	
Representative of the GIAC/GIC	Per Erik Opseth	

The Coordinating Board answers to the GGOS Consortium for all of its assigned activities, and acts as the steering committee of GGOS, as outlined in the GGOS Terms of Reference. It meets twice per year, customarily the weekend before the EGU meeting in Vienna, Austria, and the AGU meeting in San Francisco, USA.

GGOS Executive Committee

The GGOS Executive Committee serves at the direction of the Coordinating Board to accomplish day-to-day activities of GGOS tasks. The membership (Table 3) consists of both ex-officio and elected positions, the latter of which is decided in a collaborative effort between the Chair and the Coordinating Board.

Table 3: Members of the GGOS Executive Committee

GGOS Executive Committee - April 2015	
Executive Committee Members	
GGOS Chair	Hansjörg Kutterer
GGOS Vice Chair	Ruth Neilan
Director of the GGOS Coordinating Office	TBD
Directors of the GGOS Bureaus	Michael Pearlman Detlef Angermann
Voting Members (elected by CB)	Erricos Pavlis Tom Herring
Permanently Invited Guests (ex-officio)	
Immediate Past Chair of GGOS	Markus Rothacher
Chair of the GGOS Science Panel	Richard Gross
President of the IAG *(or designated representative)*	Chris Rizos (Harald Schuh, IAG Vice President)
Invited Observers	
	Srinivas Bettadpur

GGOS Science Panel

Chair:	Richard Gross (USA)	
Members:	Jonathan Bamber (UK)	Sylvie Malardel (UK)
	Aleksander Brzezinski (Poland)	Rui Ponte (USA)
	Jim Davis (USA)	Matt Rodell (USA)
	Athanasios Dermanis (Greece)	Seth Stein (USA)
	Andrea Donnellan (USA)	Tonie van Dam (Luxembourg)
	Roger Haagmans (The Netherlands)	

Purpose and Scope

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 Coordinating Board and a permanent guest at meetings of the Executive Committee. 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 and Actions

The Science Panel provides scientific support to GGOS. During the 2011-2015 quadrennium this support included participation in Consortium, Coordinating Board, and Executive Committee meetings and conference calls.

The Science Panel continues to be involved in the GGOS Working Group on Performance simulations and Architectural Trade-Offs (PLATO) with the current Chair of the Science Panel, Richard Gross, being the Co-Chair of the Working Group.

The Science Panel has been actively promoting the goals of GGOS by helping to organize GGOS sessions at major scientific conferences. During the 2011-2015 quadrennium, GGOS sessions have been organized at:

- 2011 American Geophysical Union Fall Meeting in San Francisco
- 2012 American Geophysical Union Fall Meeting in San Francisco
- 2013 American Geophysical Union Fall Meeting in San Francisco
- 2014 American Geophysical Union Fall Meeting in San Francisco
- 2012 Asia Oceania Geosciences Society – American Geophysical Union Western Pacific Geophysics Meeting Joint Assembly in Singapore
- 2013 Asia Oceania Geosciences Society Annual Meeting in Brisbane
- 2014 Asia Oceania Geosciences Society Annual Meeting in Sapporo
- 2012 European Geosciences Union General Assembly in Vienna
- 2013 European Geosciences Union General Assembly in Vienna
- 2014 European Geosciences Union General Assembly in Vienna
- 2015 European Geosciences Union General Assembly in Vienna
- 2013 American Geophysical Union Meeting of the Americas in Cancun
- 2013 International Association of Geodesy Scientific Assembly in Potsdam

In addition to helping organize sessions at scientific conferences, the GGOS Science Panel also organizes topical science workshops in order to foster discussion about the geodetic observations and infrastructure required by different scientific disciplines. One such workshop was organized during 2011-2015:

International Symposium on Geodesy for Earthquake and Natural Hazards
Matsushima, Miyagi, Japan; 22-26 July 2014

Monitoring temporal and spatial changes in the Earth's lithosphere is critical to disaster mitigation. Geodetic techniques, such as GNSS, SAR, satellite gravity missions, etc., have made significant contributions in this regard, and expectation for a greater role of the geodetic community is still growing. The Global Geodetic Observing System (GGOS) is one approach to move forward. In this symposium, 130 researchers from 16 countries met in Matsushima, northeastern Japan, to discuss the role of geodesy in disaster mitigation and how groups with different techniques can collaborate toward such a goal. A summary of the workshop was published in *Eos* [Hashimoto, M., R. Gross, and J. Freymueller, The Role of Geodesy in Earthquake and Volcanic Studies, *Eos Trans. AGU*, *95*(42), 381, 2014] and peer-reviewed proceedings of the symposium will be published as a volume in the IAG Symposia series.

Objectives and Planned Efforts for 2015-2019 and Beyond

During the next quadrennium the Science Panel will continue to participate in Consortium, Coordinating Board, and Executive Committee meetings and conference calls as well as in the PLATO Working Group. In addition, the Science Panel will continue to help organize GGOS sessions at conferences and symposia including:

- American Geophysical Union Fall Meetings
- Asia Oceania Geosciences Society Annual Meetings
- European Geosciences Union General Assemblies
- International Association of Geodesy General and Scientific Assemblies

The Science Panel will also continue to organize topical science workshops in order to determine the requirements that different scientific disciplines have for geodetic data and products. The next such workshop will be held in conjunction with the *IAU/IAG/IERS Joint Symposium on Geodesy, Astronomy, & Geophysics in Earth Rotation* that will be held in Wuhan, China during 18-23 July 2016.

GGOS Bureau of Products and Standards

Chair:	Detlef Angermann (Germany)	
Co-Chair:	Thomas Gruber (Germany)	
Members:	M. Gerstl R. Heinkelmann U. Hugentobler	L. Sánchez P. Steigenberger
Associated Members and Representatives:	J. Ádám F. Barthelmes R. Barzaghi S. Bonvalot C. Boucher M. Craymer J. Gipso T. Herring	J. Ihde J. Kusche F. Lemoine E. Pavlis G. Pétit J. Ries M. Thomas
Working Groups affiliated with this Bureau:	GGOS Working Group on ITRS Standards GGOS Working Group on Earth System Modeling	

Purpose and Scope

The Bureau of Products and Standards (BPS) is a recent redefinition of the former Bureau for Standards and Conventions (BSC), which was established as a GGOS component in 2009. This redefinition is a consequence of a restructure of the GGOS organization in 2014. The Bureau is operated by the Deutsches Geodätisches Forschungsinstitut (DGFI-TUM), the Lehrstuhl für Astronomische und Physikalische Geodäsie (APG) and the Forschungseinrichtung Satellitengeodäsie (FESG) of the Technische Universität München, within the Forschungsgruppe Satellitengeodäsie (FGS). The work of the BPS is primarily focused on the IAG Services and the products they derive on an operational basis for Earth monitoring making use of various space geodetic observation techniques such as VLBI, SLR/LLR, GNSS, DORIS, altimetry, gravity satellite missions, gravimetry, etc. The Bureau builds upon existing observing and processing systems of IAG and serves as a contact and coordinating point for the IAG Analysis and Combination Services. A representative from each of these services is included in the Bureau business as an Associated Member. Also associated with the BPS are two GGOS Working Groups: "Contributions to Earth system modeling" and "ITRS Standards" (their reports are given below).

The BPS supports the IAG in its goal to obtain products of highest possible accuracy, consistency, and temporal and spatial resolution, which should refer to a consistent reference frame, stable over decades in time. To achieve this important goal, it is a fundamental requirement that common standards and conventions are used by all IAG components for the analysis of the different space geodetic observations. The BPS also concentrates on the integration of geometric and gravimetric parameters and the development of new products, required to address important geophysical questions and societal needs.

Activities and Actions

Below is a summary of major activities and accomplishments achieved in the last two years:

- The BPS has compiled an inventory based on the standards and conventions currently in use by IAG and its components. The resulting publication "*GGOS Bureau of Products and Standards: Inventory of Standards and Conventions used for the Generation of IAG/GGOS Products*" has been reviewed by an external board and the revised version shall be published in the IAG Geodesist's Handbook 2016 and on the GGOS web site as a *living document*.
- As a major outcome this inventory presents the current status regarding standards and conventions, identifies gaps and inconsistencies and provides recommendations for improvements.
- The transition of the former BSC to the BPS, as a consequence of the restructure of the GGOS organization, has been accomplished, including the compilation of an implementation plan for the BPS and the associated GGOS components and the revision of its charter.
- The interaction between the BPS and the IAG Services as well as with other entities involved in standards and conventions has been strengthened by including representatives of these entities in the BPS board and by compiling a management plan.

Objectives and Planned Efforts for 2015-2017 and Beyond

Some major in-progress activities and planned efforts are summarized below:

- Publication of the inventory on standards and conventions in the IAG Geodesist's Handbook and on the GGOS web site as a *living document;*
- Discussion of recommendations given in the inventory and compilation of an action plan, including a task description, specification of responsibilities and time schedule;
- Evaluation of the current status of IAG/GGOS products, including an accuracy assessment with respect to the GGOS requirements;
- Initiation of efforts to identify user needs and requirements for products that are currently not provided by the IAG services;
- Supporting the GGOS Portal to provide the relevant information for IAG/GGOS products and contribute to promote geodetic products to the wider user community.

Website

http://ggos-bps.dgfi.tum.de

Selected Publications and Presentations

Angermann D., Gerstl M., Sánchez L., Gruber T., Hugentobler U., Steigenberger P., Heinkelmann R.: GGOS Bureau for Standards and Conventions: Inventory of Standards and Conventions for Geodesy. IAG Symposia 143 (in press), 2015

Angermann D., Gruber T., Gerstl M., Hugentobler U., Sánchez L., Heinkelmann R., Steigenberger P.: Inventory of standards and conventions used for the generation of IAG/GGOS products. AGU Fall Meeting, San Francisco, USA, 2014 (Poster)

Angermann D.: Bureau for Standards and Conventions. Travaux, Vol. 38, Report of the International Association of Geodesy 2011-2013, 2013

Angermann D., Gruber T., Gerstl M., Heinkelmann R., Hugentobler U., Sánchez L., Steigenberger P.: The GGOS Bureau for Standards and Conventions. IAG Scientific Assembly, Potsdam, Germany, 2013

Angermann D., Gruber T., Gerstl M., Heinkelmann R., Hugentobler U., Sánchez L., Steigenberger P.: The need of common standards and conventions for homogeneous data processing and consistent geodetic products. EGU General Assembly, Vienna, Austria, 2013

Hugentobler U., Gruber T., Steigenberger P., Angermann D., Bouman J., Gerstl M., Richter B.: GGOS Bureau for Standards and Conventions: Integrated Standards and Conventions for Geodesy. In: Kenyon, S. C.; Pacino, M. C.; Marti, U. J. (eds.) Geodesy for Planet Earth, IAG Symposia, Vol. 136, pp 995-998, Springer, 10.1007/978-3-642-20338-1_124, 2012

GGOS Working Group on ITRS Standards

Chair: Claude Boucher (France)

Purpose and Activities

This group was initially established to investigate the strategy to obtain the adoption by the International Standardization Organization (ISO) of a standardization document related to ITRS.

Following the initial work done by the group, a proposal was submitted to ISO by France. This proposal was a New Work Item Proposal (NWIP) related to ITRS submitted to the ISO TC 211 on Geographical information, to which IAG is a liaison.

ISO finally decided that a preliminary study demonstrating the importance of geodetic references at large was necessary before going further in the direction of the initial proposal. A project (19161) was therefore established within ISO TC211 WG4 and chaired by Claude Boucher. The project report was finalized in January 2015, reviewed and finally submitted to WG4 for approval and decision of further actions.

Recommendations and Planned Efforts

The report ends with some recommendations :

- To develop a standard related to ITRS
- To make further studies about the interest and feasibility of a standard on vertical references
- To make similar action for universal identification of geodetic stations
- To work to improve geodetic terminology, including update of existing standards

The GGOS WG was in stand-by during this time. But assuming that the proposal about ITRS will be ultimately approved by ISO TC211, it seems opportune to reactivate this WG with a new mandate, namely drafting the document related to ITRS, and to update the membership of this WG.

GGOS Working Group on Contributions to Earth System Modeling

Chair: Maik Thomas (Germany)

Purpose and Scope

The GGOS Working Group on "Contributions to Earth System Modeling" was established in 2011 in order to promote the development of an integrated Earth system model that is simultaneously applicable to all geodetic parameter types, i.e., Earth rotation, gravity and surface geometry, and observation techniques. Hereby, the working group contributes to:

- a deeper understanding of dynamical processes in the Earth system integrally reflected in geodetic monitoring data;
- the establishment of a link between the global time series of geodetic parameters delivered by GGOS and relevant process models;
- a consistent integration and interpretation of observed geodetic parameters derived from various observation techniques;
- the utilization of geodetic observations for the interdisciplinary scientific community (in cooperation with GGOS WG on Data and Information Systems).

The overall long-term goal is the development of a physically consistent modular numerical Earth system model for homogeneous processing, interpretation and prediction of geodetic parameters with interfaces allowing the introduction of constraints provided by geodetic time series of global surface processes, rotation parameters and gravity variations. This ultimate goal implicates the following objectives:

- promotion of homogeneous processing of geodetic monitoring data (de-aliasing, reduction) by process modeling to improve analysis of geodetic parameter sets;
- contributions to the interpretation of geodetic parameters derived from different observation techniques by developing strategies to separate underlying physical processes;
- contributions to the integration of geodetic observations based on different techniques in order to promote validation and consistency tests of various geodetic products.

Current activities focus on

- the development of consistent standards, parameters, analysis strategies and formats for all components of the unconstrained modular system model approach;
- the identification of relevant interactions among subsystems and appropriate parameterizations, in particular to represent the dynamic links between near-surface fluids and the "solid" Earth;
- the development of strategies for the separation of temporal variations of Earth rotation, gravity and geoid into individual causative physical processes.

Activities and Actions

Concerning the main task of the WG, i.e., the establishment of a physically consistent modular system model for near-surface dynamics, the work concentrated on the realization of global mass conservation and the development of appropriate modules for the consideration of interactions with the lithosphere. In order to ensure mass conservation in the modular system model approach various correction algorithms have been implemented, compared and validated. It could be demonstrated that inconsistencies due to different grid characteristics, parameterizations and spatiotemporal resolutions of the sub-models can be minimized by

most of the investigated correction algorithms. However, several problems in achieving physical consistency cannot be solved by the WG itself. This is mainly due to the fact that these difficulties can only be tackled by adequate source code developments, what is mainly the task of communities which are not focusing on geodetic observables. It is a remaining challenge to motivate these communities to remedy these deficiencies, e.g., by demonstrating the high potential of geodetic quantities in getting new insights into Earth system dynamics.

Closely related to physical consistency of sub-system models is the definition of parameter standards and of standard modules and analysis strategies for forward simulations of geodetic quantities. In several discussions it was pointed out that an achievement of these initial objectives of the WG would probably not adequately satisfy the demands of the geodetic community. Ground based, airborne and satellite based geodetic observations reflect Earth system processes on a broad range of spatial and temporal scales. The interpretation and prediction of variations of these observables require different geophysical models tailored to specific processes acting on various spatiotemporal scales. Thus, the availability of diverse model approaches and the provision of diverse model solutions does not only promote interpretations, but also offers opportunities to estimate model errors, e.g., by multi-model analyses.

The elastic response of the "solid" Earth to short-term variations of surface loading is usually modeled by applying a local isostatic model or a one-dimensional spherical Earth model from which unique sets of elastic Love numbers or elastic Green's functions are derived. These approaches implicitly ignore lateral inhomogeneities in the Earth's crustal structure. To overcome this drawback in the representation of interactions between atmosphere-hydrosphere and lithospheric dynamics a set of local Green's functions for a three-layer crustal structure has been derived. Time series of site displacements due to hydrological loading derived from model simulations applying these local Green's functions are operationally provided to the community via the GGFC/IERS Combination Center.

Objectives and Planned Efforts for 2015-2017 and Beyond

Important in-progress activities and future efforts focus on

- feasibility studies for the provision of error estimates of model-based predictions of geodetic quantities (EOP, deformation, gravity variations);
- application of forward modeling and inversion methods in order to predict geodetic quantities and to invert geodetic observations for the underlying causative processes;
- the preparation of numerical algorithms for the assimilation of geodetic products into the numerical system model approach in order to provide a tool for validation and consistency tests of various monitoring products.

GGOS Bureau of Networks and Observations

Prepared by Michael Pearlman, Carey Noll, Erricos Pavlis, Chopo Ma, Ruth Neilan, Frank Lemoine, Daniela Thaller, Bernd Richter, Roland Pail, and Sten Bergstrand

Director: Michael Pearlman (USA)

Deputy Director: TBD

Associated Members and Representatives:

- Director (Mike Pearlman/CfA),
- Secretary (Carey Noll/NASA GSFC),
- Analysis Specialist (Erricos Pavlis/UMBC),
- A representative from each of the member Services,
- A representative from the IERS, and
- A representative from each of the member working groups including the Missions Working Group, the PLATO WG, the Data and Information Working WG, and the IERS Survey and Co-location WG.

Working Groups affiliated with this Bureau:

- GGOS Working Group on Satellite Missions
- GGOS Working Group on Data and Information Systems
- GGOS Working Group on Performance Simulations and Architectural Trade-Offs (PLATO)
- IERS Working Group on Survey and Co-location

Purpose and Scope

The Bureau was organized to advocate for the implementation of ground system networks of sufficient global distribution and measurement capability to address the Earth Science and societal benefit requirements set by GGOS. At the base of GGOS are the sensors and the observatories situated around the world providing the timely, precise, and fundamental data essential for creating space geodesy products designated by GGOS. The Bureau has now been restructured into the Bureau of Networks and Observations to:

- Expand its role with the other services and techniques (gravity, tide gauges, etc.);
- Improve communication and information exchange and coordination with the space missions;
- Formally include the simulation activities;
- Formally include the site-tie component at core and co-located sites; and
- Include the Data and Information Systems activity.

Core sites are those with co-located SLR, VLBI, GNSS and DORIS (where available). Co-location sites are those with either SLR or VLBI, plus GNSS or DORIS. At some point it is anticipated that the complex of instruments will be expanded to include gravity field and other surface measurements.

To date, primary emphasis has been placed on improving the infrastructure needed to provide the evolving global reference frames. Studies and simulations tell us that we will need the equivalent of 32 new technology core sites with VLBI, SLR, GNSS and DORIS to achieve a

reference frame that will permit mm accuracy at 0.1 mm/year stability over decades as specified by GGOS. A major focus of Bureau has been improved network capability, geographic coverage, and upgrade of the Core and Co-location Network sites necessary for the improvement of the reference frames. Activities include advocating for new and increased participation, encouraging formation of new partnerships to develop new sites, monitoring the status of the networks and projecting their future capabilities.

The Bureau has now been expanded to better define the requirements and integrate the non-geometric services of the IAG (gravity service, tide gauge networks, etc.) into the GGOS affiliated network. The expansion of the Bureau also includes capability to strengthen communication with the space missions, provide simulation activities to project network capability, improve data archiving/access functions, and standardize and improve site ties.

The Bureau looks to the GGOS Science Council and the Executive Committee for overall direction, but also recognizes that scientific and societal benefits will accrue through connection among ground based techniques and close support for satellite missions.

Elements within the Bureau are intended to work as an integrated team whose main focus is to deploy and upgrade the ground networks to collect the data necessary to support the required space geodesy data products. The Bureau consists of the following organizational elements:

- Services Network Representation (IGS, IVS, ILRS, IDS, IGFS, tide gauge network, etc.)
- Working Groups
  - Missions
  - Performance Simulations & Architectural Trade-Offs (PLATO)
  - Data and Information Systems
  - Ground Survey and Co-location (IERS WG)

The Bureau of Networks and Observations is the Bureau of the Services; it is run by the services and advocates for the services, and brings to GGOS the point of view of the services in policy and decision-making.

The Role of the Bureau is:

- Provide a forum for the Services and Working Groups to share and discuss plans, progress, and issues, and to develop and monitor multi-entity efforts to address GGOS requirements;
- Actively promote, sustain, improve and evolve the integrated global geodetic ground-based infrastructure needed to meet requirements for Earth science and societal benefits;
- Lead efforts for the integration of various ground observation networks within the GGOS affiliated Network;
- Coordinate the international geodetic services' activities that are the main source of key data and products needed to realize stable global reference frames and other data products essential to study changes in the dynamic Earth System and characterize key Earth Science parameters for societal benefits.

Activities and Actions

Meetings

Since 2009, the Bureau holds regular meetings, typically in conjunction with scientific meetings such as the Fall AGU and EGU; thus far, a total of thirteen Bureau meetings have been

organized in this manner. These meetings provide a forum for various entities and service representatives to present progress and future plans. All presentations given during these meetings, summaries, and lists of attendees are available through the Bureau website (http://www.ggos.org/Components/BNC/BNChome.html).

GGOS Affiliated Network Developments

In August 2011 the Bureau developed and issued a Call for Participation (CfP) in the "Global Geodetic Core Network: Foundation for Monitoring Earth System" for the development, implementation, and operation of the GGOS affiliated core network. The long-term goal of the core network is to implement a global network of ground-based space geodetic sites that provide 1 mm and 0.1mm/year quality measurements to satisfy the GGOS Scientific Objectives (GGOS 2020). The network will evolve over time with new technologies replacing legacy technologies and new sites being established. The quality of geodetic data products will improve as the network progresses. With the long horizon required to achieve the full core network, sites with co-located, but less than the full core configuration, will continue to play a vital role in the evolution of the data products.

A total of 19 submissions were received covering 114 sites that included legacy core sites, legacy/new technology co-location sites, core and co-location sites under development, and sites offered for future participation; a summary of the CfP responses is available on the Bureau's website: (http://192.106.234.28/Components/BNC/update%20Apr2013/GGOS_CfPResponseSummaries_20150106.pdf).

Related Bureau Documentation

As part of the Core Network activity, the Bureau has facilitated the creation of several key documents:

- "GGOS Site Requirements for Fundamental Stations" document: http://192.106.234.28/Components/BNC/update%20Apr2013/GGOS_SiteReqDoc_1207.pdf
- A guidelines document for site characterization of the GGOS network sites was developed, "The Global Geodetic Core Network: Foundation for Monitoring the Earth System": http://192.106.234.28/Components/BNC/update%20Apr2013/GGOS_sitecategorization.pdf
- A plan to define the process by which GGOS determines the extent of the needed infrastructure, including the scope and specification of the network, conditioned on the existing or plausible technology available, "GGOS Infrastructure Implementation Plan": http://192.106.234.28/Components/BNC/GGOS_Infrastructure_Plan_V3_130321.pdf
- A plan to assess the current and future plans for a GGOS core network, including projections five to ten years in the future, "Space Geodesy Network Model": http://192.106.234.28/Components/BNC/candidatesites_130122.pdf
- Documents developed within the context of NASA's Space Geodesy Project, evaluating several sites as potential core sites; these documents are available from the SGP website at: http://space-geodesy.gsfc.nasa.gov/publications/papers.html
- A summary report issued from the TLS (Terrestrial Laser Scanner) Workshop that was held at NASA GSFC, September 08-10, 2008: http://192.106.234.28/Components/BNC/Summary%20report%20from%20the%20TLS%20(Terrestrial%20Laser%20Scanner).pdf

Objectives and Planned Efforts for 2015-2017 and Beyond

Plan for the Next Reporting Period

In its role to support the services and better serve the users, the GGOS Bureau of Networks and Observations will:

- Advocate for implementation of the global space geodesy network of sufficient capability to achieve data products essential for GGOS;
  - Update the Bureau section of the GGOS website for public use including status, plans, and issues for the Bureau entities (June 2015);
  - Provide status and plans reports from the Bureau at EGU, AOGS (August 2015), AGU (December 2015) and other public meetings; (April 2015),
  - Continue the Bureau Call for Participation and work with new potential groups interested in participation;
  - Meet with interested parties and encourage partnerships;
- Provide a forum for the Services and Working Groups to meet, discuss status and plans, and examine common interests and requirements;
- Organize meeting at EGU, AGU, and other opportunities;
- Update the Site Requirements Document (with the IAG Services) (July 30, 2015);
- Monitor and project the status and evolution of the GGOS space geodesy network in terms of location and performance (with the IAG Services);
  - Issue next questionnaire and compile responses (June 30, 2015};
- Coordinate the effort of the services to implement procedures to provide test-based estimates of their data quality and report (First discussion at the Bureau's meeting at EGU 2015);
- Facilitate efforts to integrate other ground networks (gravity field, tide gauges, etc.) into the GGOS Network to support GGOS requirements (progress report at EGU 2016);
- Support the technical services on the promotion of recommended technologies/configurations and procedures in the establishment of new sites and the upgrading of current sites, and in the evaluation of performance of new stations and new capabilities after they become operational;
- Working Group on PLATO: Project future network capability and examine trade-off options for station deployment and closure, technology upgrades, impact of site ties, etc.
  - Using simulation techniques already established, use the updated stations status and projections to project network capability over the next 5 and 10 years periods (first report EGU 2015 by Pavlis);
  - Based on the updated station projections, estimate the GNSS tracking load that the SLR Network can sustain (Bureau meeting at AGU 2015);
  - Make recommendations on network configuration based on simulations and trade-off studies.

    For more details see see the PLATO WG subsection, below.
    - Working Group on Data and Information: Develop a metadata strategy for all ground-based measurement techniques (WG on Data and Information)
  - Develop a document summarizing the need, the activities underway by independent groups, and the pertinent references (June 2015);

  - Organize a meeting of the interested parties to discuss how we can integrate/utilize the separate space geodesy metadata activities, and provide organizational oversight to carry it through (October 2015).

    For more detail see WG on Data and Information Systems subsection, below.

- Working Group on Missions: Improve coordination and information exchange with the missions for better ground-based network response to mission requirements and space-segment adequacy for the realization of GGOS goals
  - Agree in the content and develop a missions section on the GGOS website for public assess; implement a procedure to keep the section up-to-date (September 2015);
  - Review of inventory/repository of current and near-future satellite missions (Bureau meeting at EGU 2016);
  - Evaluation of contribution of current and near-future missions to GGOS goals (Bureau meeting at AGU 2016)
  - Finalize Science and User requirements document for future gravity missions with IGFS and forward to the IUGG via ESA for formulation into a joint resolution (June 2015);

    For more detail see the WG on Satellite Missions subsection, below.

    - IERS Working Group on Survey and Co-location: Standardize site-tie measurement, archiving, and analysis procedures, maintain a current site-tie archive; and encourage additional groups to help support the network site-tie task
  - Develop a guidelines document of standard nomenclature (December 2015);
  - Develop a plan for an outreach approach to station managers at co-location sites to stress the need for accurate local ties and the need for seeking local survey capability; Stress outreach to surveying teams in China, Russia and Japan in order to establish common guidelines (EGU 2016);
  - Coordinate the effort of the services to implement procedures to determine system reference points and their accuracies (First discussion Bureau meeting in April 2015);

    For more detail see the IERS WG on Survey and Co-location subsection, below.

    - Support GGOS submissions to GEO, CEOS and other international organizations.

The evolution of the networks will be a long-term endeavor (10-20 years), but the evolution in the networks, including both the core and participating co-location sites, and the associated modeling and analyses will provide steady and very useful improvements in the data products. The evolving data and data products will be a major driver for developing and validating of the new models and analysis techniques.

*Website***:** See (http://www.ggos.org/Components/BNC/BNChome.html).

Publications and Presentations

M. Pearlman, E. Pavlis, C. Ma, Z. Altamimi, C. Noll, D. Stowers, "Space Geodesy Networks to Improve the ITRF", Abstract EGU2011, presented at EGU 2011-4786 General Assembly, Vienna Austria, April 04-08, 2011.

M. Pearlman, E. Pavlis, C. Ma, Z. Altamimi, C. Noll, D. Stowers, "Ground Based Space Geodesy Networks Required to Improve the ITRF", presented at the International Symposium on Space Geodesy and Earth System, Shanghai, China, August 18-20, 2012.

M. Pearlman, C. Ma, E. Pavlis, C. Noll, S. Wetzel, J. Park, R. Neilan, A. Ipatov, "Evolution of the Global Space Geodesy Network", Abstract EGU2013-3554, presented at EGU 2013 General Assembly, Vienna, Austria, April 07-12, 2013.

M. Pearlman, E. Pavlis, C. Noll, C. Ma, S. Wetzel, G. Appleby, R. Neilan, "GGOS Global Space Geodesy Networks and the Role of Laser Ranging", Abstract 13-0203, presented at the 18th International Workshop on Laser Ranging, Fujiyoshida, Japan November 11-15, 2013.

M. Pearlman, E. Pavlis, C. Ma, C. Noll, R. Neilan, D. Stowers, S. Wetzel, "The GGOS Global Space Geodesy Network and its Evolution", Abstract G53C-01, presented at 2013 Fall AGU Meeting, San Francisco, CA, December 9-13, 2013.

M. Pearlman, A. Ipatov, J. Long, C. Ma, S. Merkowitz, R. Neilan, C. Noll, E. Pavlis, V. Shargorodsky, D. Stowers, S. Wetzel, "The Global Space Geodesy Network: Activities Underway", Abstract EGU2014-3140, presented at EGU 2014, Vienna Austria, April 28-May 02, 2014.

M. Pearlman, "The Role of CORE and Co-location Sites and the Activities Underway to Improve the Global Space Geodesy Network", Abstract 3044, presented at the 19th International Workshop on Laser Ranging, Annapolis MD, Oct. 27-31, 2014.

M. Pearlman, A. Ipatov, F. Lemoine, J. Long, C. Ma, S. Merkowitz, R. Neilan, C. Noll, E. Pavlis, H. Schuh, V. Shargorodsky, D. Stowers, S. Wetzel, "The Expanding Core and Co-location Space Geodesy Network and the Importance of High Latitude Sites", presented at Fifth Symposium on Polar Science, December 02-05, 2014.

M. Pearlman, C. Ma, C. Noll, E. Pavlis, H. Schuh, T. Schoene, R. Barzaghi, S. Kenyon, "The GGOS Bureau of Networks and Observations and an Update on the Space Geodesy Networks", Abstract EGU2015-7420, presented at EGU 2015 General Assembly, April 13-17, 2015, Vienna, Austria, April 12-17, 2015.

GGOS Working Group on Satellite Missions

Chair: Roland Pail (Germany)
Co-Chair: Jürgen Müller (Germany)

Purpose and Scope

The GGOS Satellite Mission Working Group (SMWG) is established in December 2008, under the lead of C.K. Shum, and more than 20 members agreed to serve on this Working Group. In December 2010, Isabelle Panet was appointed as new Chair, and in December 2013 Roland Pail took over the Chair.

The purpose and scope is the coordination, advocating and information exchange with satellite missions as part of the GGOS space infrastructure, for a better ground-based network response to mission requirements and space-segment adequacy for the realization of the GGOS goals.

The SMWG is set-up as an international panel of experts, with consultants of national and international space agencies.

Satellite missions are a prerequisite for monitoring change processes in the Earth system on a global scale with high temporal and spatial resolution. Therefore, beyond purely scientific objectives they meet a number of societal challenges, and they are an integral part of the GGOS infrastructure and essential to realize the GGOS goals. The aspiration of the SMWG is to monitor the availability of satellite infrastructure, to propose and to advocate new missions or mission concepts, especially in case that a gap in the infrastructure is identified.

Activities and Actions

1. *Assessment of current and near-future satellite infrastructure, and their compliance with GGOS 2020 goals*

   An inventory of the GGOS satellite infrastructure has been finalized, and a list of satellite contributions to fulfil the GGOS 2020 goals is close to finalization. First steps towards identifying gaps in the future GGOS satellite infrastructure, to gather needs for future mission in order to achieve the GGOS 2020 goals, have been done.

2. *Support of proposals for new mission concepts and advocating needed missions*

   SMWG initiated and discussed an IUGG resolution (Melbourne, 2011) regarding the importance of future potential field missions, and initiated a letter from IUGG, signed by the IUGG president, to NASA and ESA headquarters to emphasize this resolution.

   Initiation and organization of an International Workshop on the "Consolidation of Science and User Requirements for a next gravity field mission configuration", which was organized and held in Herrsching, 26./27. September 2014. Under the umbrella of IUGG and GGOS, a working team of more than 50 international lead scientists in the disciplines continental hydrology, cryosphere, ocean, and solid Earth agreed on consolidated science and user requirements for a sustained future satellite gravity observing system. This document is input to a joint ESA/NASA working group on a next generation gravity mission constellation (beyond GRACE-FO).

3. *Interfacing and outreach*

   The SMWG is consultant for the GGOS EC concerning CEOS issues. Close cooperation exists to the Bureau of Standards and Products, and the Sub-Commissions 2.3 and 2.6 of IAG. Additionally, there are strong interfaces to national and international space agencies.

Objectives and Planned Efforts for 2015-2017 and Beyond

- Work with the Coordinating Office to set up and maintain a Missions WG section on the GGOS website;
- Set-up and maintain an inventory/repository (accessible through the GGOS Website and/or Portal) of current and near-future satellite missions;
- Evaluate the contribution of current and near term satellite missions to the GGOS2020 goals;
- Work with the Focus Areas (formerly Themes) and the Science Committee to establish the required mission roles and to identify the critical gaps in mission infrastructure;
- Work with GGOS Executive Committee, Focus Areas, and data product development activities (e.g. ITRF) to advocate for new missions to support GGOS goals
- Support the Executive Committee and the Science Committee in the GGOS Interface with space agencies,
- Support the GGOS position at the next CEOS/GEO, etc. Meeting.

Action no.	Action	KO + 6 m	KO + 12 m	KO + 18 m	KO + 24 m
001	Set-up of Mission WG section on GGOS website				
002	Maintenance of Mission WG section on GGOS website				
003	Review of inventory/repository of current and near-future satellite missions				
004	Maintenance of inventory/repository of current and near-future satellite missions				
005	Evaluation of contribution of current and near-future mission to GGOS 2020 goals				
006	Interfacing with Focus Areas (formerly Themes) and GGOS Science Committee to identify critical gaps in the satellite infrastructure				
007	Finalization and publishing (outreach) of Science and User Requirements Document for future gravity field mission				
008	Support advocating of new missions				
009	Supporting GGOS EC and SC in the interfacing with space agencies				
010	Supporting GGOS positions in preparation to CEOS/GEO meetings				

These tasks will require interfacing with other components of the Bureau, especially the ground networks component, the simulation activity (PLATO), as well as the Bureau of Standards and Products.

Publications and Presentations

Pail R., Bingham R., Braitenberg C., Eicker A., Horwath M., Longuevergne L., Panet I., Rolstad-Denby C., Wouters B. (2015): Consolidated science and user requirements for a next generation gravity field mission. Geophysical Research Abstracts, Vol. 17, EGU2015-1648, EGU General Assembly 2015.

Pail R., Bingham R., Braitenberg C., Eicker A., Floberghagen R., Haagmans R., Horwath M., Johnson T., Longuevergne L., Panet I., Rolstad-Denby C., Wouters B. (2014): **Consolidated science requirements for a next generation gravity field mission.** 5th International GOCE User Workshop, Paris, 28.11.2014

GGOS Working Group on Data and Information Systems

Prepared by Carey Noll and Bernd Richter
Chair: Bernd Richter (Germany)
Co-Chair: Carey Noll (USA)

Role (Goals and Objectives)

- Promote the use of metadata standards and conventions and recommend implementations of metadata management for GGOS in the pursuit of a metadata policy;
- Promote interoperability among participating data centers with other databases and services;
- Develop strategies to protect the intellectual properties on data and products;
- Align metadata standards with GEOSS approach and methodology, interface on data standards with to GEO and ICSU.

The current focus of the WG is on developing standards for metadata that can be utilized by the space geodesy community. Metadata typically encompass critical information about the measurements that are required to turn these measurements into usable scientific data. Metadata also includes information that supports data management and provides a foundation for data discovery. Data centers extract metadata from incoming data sources and also augment that metadata with information from other sources. It is typical for data centers to store the metadata in databases in order to manage the data in their archives and to distribute both data and metadata to data users. Metadata can further be utilized by data discovery applications to allow users to find data sets of interest. In order to be effective, metadata need to be simple to generate and maintain. They must be consistent and informative for the archivist and the user.

GGOS is seeking a metadata schema that can be used by all of its elements for standardized metadata communication, archiving, and retrieval. First applications would be automated distribution of up-to-date stations configuration and operational information, data archives and catalogues, and procedures and central bureau communication. Several schemas that show promise have been under development by SOPEC (Scripps), GML (Australia/NZ), etc. The intent is that data need be entered only from an initial source (a station, a Data Center, an Operations Center, data products, etc.) and would then flow to and be integrated into those metadata files where users would have access. The plan is to organize a meeting, probably in early August at UNAVCO in Boulder, for representatives from the Services, the Data Centers, the Science Community, etc. to give each of the schema developers an opportunity to preach his wears and allow discussion on the pros and cons of each.

The objective is to try to come to closure on a schema that we could as a community adopt for general implementation. Groups would not be obligated to a rapid implementation schedule, but would commit to the agreed schema when they are ready to begin the process.

Tasks

- Develop a document summarizing the need, the activities underway by independent groups, and the pertinent references (June 2015);
- Organize a meeting of the interested parties to discuss how we can integrate/utilize the separate space geodesy metadata activities, and provide organizational oversight to carry it through (August 2015).

Gary Johnston has agreed develop a white paper to spell out the need and the plan to use as a basis for a Call for Participation in the meeting to be issued by the Bureau. This workshop is currently planned for August 2015 in Boulder, CO.

Organization

The WG will is currently chaired by Bernd Richter with current co-chair Carey Noll. Additional members with interest in data management within the services perform necessary research, provide material for the website, presentation material, and other documentation.

Reporting

The Working Group will give oral (PPT) reports on accomplishments, tasks underway, plans, and current obstacles at each of the Bureau meetings. Written reports may sometimes be required for Bureau reporting as required by the GGOS leadership. The WG will maintain a page on the GGOS website to keep the community aware of progress and work underway.
A report summarizing the planned metadata workshop and including actions and plans will be issued.

GGOS Working Group on Performance Simulations & Architectural Trade-Offs (PLATO)

Prepared by Daniela Thaller
Chair: Daniela Thaller (Germany)
Co-Chair: Richard Gross (USA)

Role (Goals and Objectives)

- Use simulation techniques to assess impact on reference frame products of: network configuration, system performance, technique and technology mix, co-location conditions, site ties, and space ties (added spacecraft, etc.);
- Use and develop improved analysis methods for reference frame products by including all existing data and available co-locations (i.e., include all satellites and use all data types on all satellites);
- Make recommendations on network configuration based on simulations and trade-off studies.

Tasks:

- Develop optimal methods of deploying next generation stations, and estimate the dependence of reference frame products on ground station architectures;
- Estimate improvement in the reference frame products as co-located and core stations are added to the network;
- Estimate the dependence of the reference frame products on the quality and number of the site ties and the space ties;
- Estimate the improvement in the reference frame products as other satellites are added, e.g., cannonball satellites, LEO, GNSS constellations;
- Estimate the improvement in the reference frame products as co-locations in space are added, e.g., use co-locations on GNSS and LEO satellites, add special co-location satellites (GRASP, NanoX, etc.);
- In support of the SLR tracking on GNSS satellites, use an agreed measure of SLR ranging performance, to examine optimal tracking strategies, and to develop the optimal deployment of the tracking data for reference frame products;
- Conduct simulations for co-location satellites – how much would it help us? How many data do we need? How accurately do we need to know the dimensions on the satellite and other s/c-related parameters (e.g., ties between instruments on board, satellite attitude);

Organization

The WG will have a chair, a co-chair and WG team members who will be involved with the planning and conduct of the simulations and the extended analysis methods. The WG will define the roles for its members' participation. Associate members may attend meetings, provide information, and contribute to the discussion.

The Chair and Co-Chair are Daniela Thaller and Richard Gross.

The Working Group will establish liaisons with the networks entity, the other GGOS working groups (e.g., Satellite Missions) and the Focus Areas (formerly Themes) to enhance communication and coordination, and other GGOS and IAG entities as necessary, especially the IERS WG on Site Survey and the ILRS Working Group LARGE.

Reporting

The Working Group will give oral (PPT) reports on accomplishments, tasks underway, plans, and current obstacles at each of the Bureau meetings. Written reports may sometimes be required for Bureau reporting as required by the GGOS leadership. The WG will maintain a page on the GGOS website to keep the community aware of progress and work underway.

The WG members will give presentations at scientific conferences about their individual contributions to fulfill the WG tasks. Publications in appropriate journals are also envisaged.

IERS Working Group on Survey and Co-location

Chair: Sten Bergstrand (Sweden)
Co-Chair: John Dawson (Australia)

Role (Goals and Objectives)

- Work with the IGN to maintain a comprehensive site survey and site tie data base;
- Standardize site-tie measurement procedures, standards and analyses techniques;
- Work with the Data Centers to have results from all of the site tie measurement;
- Work with the IERS, the Services and GGOS to encourage more groups to gain site tie survey and analysis capability;
- Help set site tie measurement priorities.

Tasks

- The IGN is working on a guideline document of standard nomenclature to overcome the present confusion among survey groups and between survey groups and users;
- Survey responsibilities have been too widespread and uncoordinated; knowledge on procedures and processing must be shared; dedicated point of contact with each of the Services have been assigned, The WG will try to reach out to surveying teams in China, Russia and Japan in order to establish common guidelines. The WG is discussing an out-reach approach to station managers at co-location sites to stress the need for accurate local ties and the need for seeking local survey capability;

  Issue: Do we need a policy shift for local ties?
  As long as there are researchers performing measurements and they thrive on publications, how can we increase the number of local ties? Publications rely on novelty, production on consistency. A remake of a local tie survey should ideally use exactly the same procedure and hopefully produce equivalent results. How do you publish local tie number two?

Organization

The WG will have a chair, a co-chair and WG team members who will be involved with the planning and conduct of WG activities. The WG will define the roles for its member's participation.

The Working Group will establish liaisons with the networks entity, the other working groups and the Themes to enhance communication and coordination, and other GGOS and IAG entities as necessary.

Reporting

The Working Group will give oral (PPT) reports on accomplishments, tasks underway, plans, and current obstacles at each of the Bureau meetings. Written reports may sometimes be required for Bureau reporting as required by the GGOS leadership. The WG will maintain a page on the GGOS website to keep the community aware of progress and work underway.

GGOS Focus Area 1: Unified Global Height System

Chair: Michael G. Sideris (Canada)
Co-Chair: Johannes Ihde (Germany)

Members: Colleagues who have contributed to the work of Theme 1 are basically the members of the JWG 0.1.1 and the Height System Unification ESA project (listed on the web sites given below)

Purpose and Scope

The main objective of Focus Area 1 (formerly Theme 1) is the unification of the existing vertical reference systems around the world through the definition and realization of a global vertical reference system that

- will support geometrical (ellipsoidal) and physical (normal, orthometric, geoidal) heights world-wide with centimetre precision (10^{-9}) in a global frame;
- will enable the unification of all existing physical height systems (i.e., all geopotential differences shall be referred to one and the same reference equipotential surface with potential W_o); and
- will provide high-accuracy and long-term stability of the temporal height changes (dh/dt, dH/dt, dN/dt) with 10^{-9} precision.

A World Height System (WHS) shall be realized with a global combined network, which will integrate at set of terrestrial reference stations high-precision absolute and relative gravity, levelling with gravity reductions, and GNSS and tide gauge observations. For this purpose, it will use contributions from all IAG Commissions, and the available databases, standards and infrastructure of the IAG/GGOS Services.

Activities and Actions

During the last four years, the Theme members developed and worked on a set of short- and medium-term goals. The short-term ones can be summarized under the banner "Establish a global vertical reference surface and its geopotential value W_o", and include the following:

1. Refinement of standards and conventions for the definition and realization of a WHS, including unification of standards and conventions that are used by the "geometry" and "gravity" Services of the IAG.
2. Establishment of a global vertical reference level.

The work of items #1 and #2 was accomplished by the Joint (Theme 1 with Commissions 1 and 2, and IGFS) Working Group JWG 0.1.1: Vertical Datum Standardization, chaired by L. Sánchez. The main purpose of the joint working group is to provide a reliable W_0 value to be introduced as the conventional reference level for the realization of a Unified Global Height System. The activities of JWG 0.1.1 during the reporting period concentrated on the empirical estimation of this value using the newest available representations of the Earth's surface and gravity field. The computation of a new *best estimate* for the global W_0 value has been accomplished, and a suitable W_0 as reference level for the Unified Heights System shall be recommended. This recommendation should be supported by an IAG resolution focused on the establishment of an International Height Reference System and to be adopted in the IUGG General Assembly in Prague. Activities and results of this working group were presented in

regional conferences and the 2013 IAG Scientific Assembly in Potsdam, and the 3rd IGFS General Assembly, in July 2014 in Shanghai.
The medium-term goals can be summarized under the banner "Develop GGOS products for the realization of a WHS", and include the following:

3. Recommendation for a global vertical reference frame.
4. Guidelines/procedures for height system unification.

Regarding #3, members of GGOS Theme 1 and the Bureau for Standards and Conventions (BSC) prepared in 2014 a Proposal for the Definition and Realization of an International Height Reference System (IHRS); available from Johannes Ihde. Besides its importance to science in general, such an IHRS is also needed for GGOS's Theme 3 - Understanding and Forecasting Sea-Level Rise and Variability, and for the joint activities of the IAG Commission 2 - Gravity Field and the Consultative Committee for Mass and related quantities (CCM) that have to agree on a Strategy for Metrology in Absolute Gravimetry. It is urgently necessary to remove the inconsistencies between geometric products and products related to the Earth's gravity field, in order to enable the development of integrated geodetic applications. Taking a broader view, GGOS and IAG should maybe support the establishment of an International Height and Earth Gravity Reference System.

A lot of contributions to item #4 came for the project "GOCE+: Height System Unification with GOCE", which was carried out by the Technical University of Munich (Germany), the University of Calgary (Canada), the National Oceanography Center (UK) and the Bundesamt für Kartographie und Geodäsie (Germany) in the frame of the Support to Science Element of ESA's Earth Observation Envelope Program. The main objectives of this project, namely to (i) evaluate and improve the methodology for height determination and height system unification, (ii) demonstrate the feasibility of the height system unification using GOCE derived geoid models and investigate the impact of GOCE for this purpose, and (iii) provide a roadmap for the definition and realization of globally consistent and accurate height reference system, have been achieved. Documents can be found in the links provided below under Publications and Presentations.

Objectives and Planned Efforts for 2015-2017 and Beyond

The long-term objectives of Theme 1 can be placed under the banner "Maintain and use in practice the WHS" so that it can service the vertical datum needs of not only geodesy but also other geosciences such as, e.g., hydrology and oceanography. They include the following:

5. Development of a registry (metadata) containing the existing local/regional height systems and their connections to the global one.
6. Determination and modeling of the temporal changes of the vertical reference frame.
7. Update the Unified Global Height System definition and realization as needed, based on future improvements in geodetic theory and observations.

It is clear that in order to accomplish these objectives, the work of Theme 1 and JWG 0.1.1 should be continued by broader teams of researchers that will include colleagues from all continents.

Websites

JWG 0.1.1: http://whs.dgfi.tum.de/index.php?id=1
ESA project: www.goceplushsu.eu

Publications and Presentations

There is an extensive list of publications and presentations that cannot be listed in this brief report. However, many of them can be found in the following web sites:

Special issue of *Journal of Geodetic Science* on Regional and Global Geoid-based Vertical Datums, Eds. Michael Sideris and Georgia Fotopoulos: http://www.degruyter.com/view/j/jogs. 2012.2.issue-4/issue-files/jogs.2012.2.issue-4.xml

ESA project final documents: http://www.goceplushsu.eu/gpweb/gc-cont.php?p=65

ESA project presentations/publications: http://www.goceplushsu.eu/gpweb/gc-cont.php?menu=16

Joint Working Group 0.1.1: Vertical Datum Standardisation (JWG 0.1.1)

supported by GGOS Focus Area 1, IAG Commission 1 (Reference Frames), IAG Commission 2 (Gravity Field) and the International Gravity Field Service (IGFS)

Chair: Laura Sánchez (Germany)

Members:
J. Ågren (Sweden
R. Cunderlík (Slovakia)
N. Dayoub (Syria)
J. Huang (Canada)
R. Klees (The Netherlands)
J. Mäkinen (Finland)
K. Mikula (Slovakia)
Z. Minarechová (Slovakia)
P. Moore (United Kingdom)
D. Roman (USA)
Z. Šima (Czech Republic)
C. Tocho (Argentina)
V. Vatrt (Czech Republic)
M. Vojtiskova (Czech Republic)
Y. Wang (USA)

Report of Activities

During the 2011 IUGG General Assembly, GGOS, the IAG Commissions 1 (Reference Frames) and 2 (Gravity Field) and the IGFS established a joint working group devoted to the Vertical Datum Standardization. This working group (called JWG 0.1.1) supports the activities of GGOS Focus Area 1 (formerly Theme 1) Unified Global Height System; in particular, to recommend a reliable geopotential value W_0 to be introduced as the conventional reference level for the realization of an International Height Reference System (IHRS). At present, the most commonly accepted W_0 value corresponds to the best estimate available in 1998 (see Petit and Luzum 2010, Table 1.1); however, this value presents discrepancies larger than 2 m^2s^{-2} with respect to recent computations based on the latest Earth's surface and gravity field models. In this context, the first activities faced by JWG 0.1.1 concentrated on (1) making an inventory about the published W_0 computations to identify methodologies, conventions, standards, and models presently applied (cf. Sánchez 2012) and (2) bringing together the different groups working on the determination of a global W_0 in order to coordinate these individual initiatives for a unified computation (cf. Sánchez et al. 2014).

Following aspects were analysed in the unified computation:

- Sensitivity of the W_0 estimation on the Earth's gravity field model
- Dependence of W_0 on the omission error of the global gravity model
- Influence of the time-dependent Earth's gravity field changes on W_0
- Sensitivity of the W_0 estimation on the mean sea surface model
- Influence of time-dependent sea surface changes on W_0
- Effects of the sea surface topography on the estimation of W_0
- Dependence of the W_0 empirical estimation on the tide system
- Weighted computation based on the accuracy of the input data to estimate the influence of the input data uncertainties on the W_0 estimation.

The different calculations carried out within the JWG 0.1.1 demonstrate that the 1998 W_0 value (62 636 856.0 ± 0.5 m^2s^{-2}) is not in agreement with the newest geodetic models describing geometry and physics of the Earth (see Table 4). The estimations without considering the accuracy of the input data suggest as a best estimate the value 62 636 854.0 m^2s^{-2} (see presentation at the IAG General Assembly 2013 in Potsdam, Germany). However, if weights based on the accuracy of the input data are considered, the W_0 estimation decreases about 0.3 m^2s^{-2} (Fig. 1). Since the computations are based on yearly mean sea surface models, the mean value for W_0 would refer to the mean epoch between 1992.9 and 2013.5 (i.e. 2003.2). However, it would be convenient to adopt a W_0 value valid for a more recent epoch, for example 2010.0. As reference level, the adopted W_0 has to be fixed (without time variations); but it has to have a clear relationship with the mean sea surface level (as this is the convention for the realization of the geoid). According to this, a suitable recommendation for the IHRS reference level is to introduce the potential value (rounded to one decimal) obtained for the year 2010 after fitting the weighted yearly W_0 estimations by means of a lineal regression: 62 636 853.4 m^2s^{-2}. At the time presenting this report (May 2015), two publications are in preparation: the first one describes in detail the computation strategy, conventions and models applied for the W_0 estimation; the second one concentrates on supporting the recommendation of the W_0 value as reference level for the IHRS, including a description about the procedure to realize this value at regional and local level.

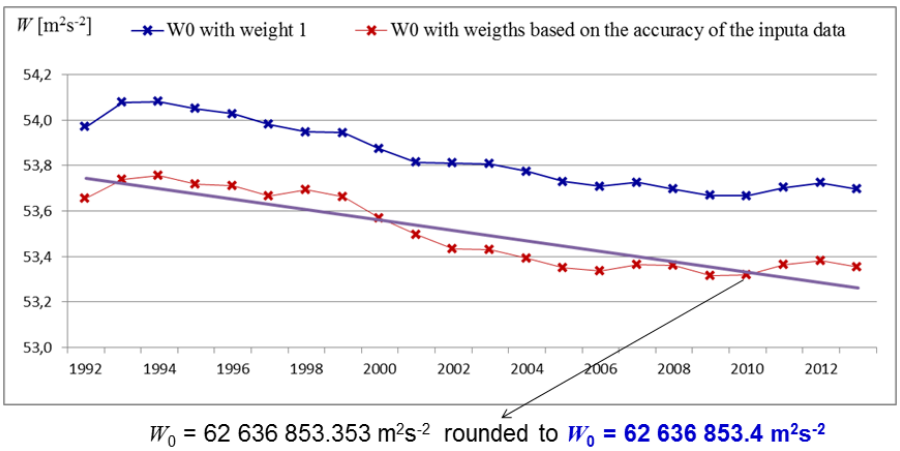


Fig. 1: Comparison of the W_0 estimation assuming the input data free of error and a weighed estimation including the inverse of the input data variances as weighting factor. The potential value (rounded to one decimal) obtained for the year 2010 after fitting the weighted yearly W_0 estimations by means of a lineal regression is a suitable recommendation to define the reference level of the International Height Reference System.

Table 4: W_0 estimations carried out by the members of the JWG 0.1.1 (taken from Sánchez et al. 2014, page 208)

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Table 1 Summary of the W_0 estimates delivered by the four groups working on the W_0 determination in the frame of the JWG 0.1.1

Group	MSS	Area	GOCO03S	EIGEN-6C	EGM2008
Prague	Jason 1	67°N/S	54.28	54.25	54.24
		60°N/S	53.75	53.73	53.96
Bratislava	DTU10	82°N/S	54.00	53.95	53.96
		67°N/S	53.53	53.49	53.49
	CLS11	82°N/S	54.30	54.26	54.26
		67°N/S	53.82	53.79	53.79
Latakia	DTU10	80°N/S	54.11	54.11	54.11
		70°N/S	53.91	53.92	53.92
		60°N/S	53.07	53.08	53.07
	CLS11	80°N/S	54.42	54.43	54.43
		70°N/S	54.23	54.24	54.23
		60°N/S	53.38	53.40	53.39
	DTU10 + ECCO2	70°N/S	53.94	53.95	53.95
		60°N/S	53.87	53.88	53.87
	CLS11 + ECCO2	70°N/S	54.26	54.27	54.26
		60°N/S	54.18	54.20	54.19
Munich	DTU10	82°N/S	54.02	53.98	53.97
		67°N/S	53.55	53.53	53.53
		60°N/S	53.11	53.12	53.12
	CLS11	82°N/S	54.31	54.29	54.30
		67°N/S	53.86	53.82	53.83
		60°N/S	53.44	53.41	53.40

The values are given in [$m^2\ s^{-2}$] and the constant 62,636,800 should be added. Applied methodologies are described in Burša et al. (1999), Čunderlik and Mikula (2009), Dayoub et al. (2012) and Sánchez (2009), respectively

Publications

Čunderlík R.: Determination of Wo from the GOCE Measurements Using the Method of Fundamental Solutions. In: International Association of Geodesy Symposia, forts on-line, doi: 10.1007/1345_2015_39, 2015

Čunderlik R., Minarechová Z., and Mikula K.: Realization of WHS Based on the Static Gravity Field Observed by GOCE. In: Marti U. (ed,), Gravity, Geoid and Height Systems. IAG Symposia Series 141: 211-220, doi: 10.1007/978-3-319-10837-7_27, 2014

Dayoub N., Edwards S.J. and Moore P.: The Gauss-Listing potential value Wo and its rate from altimetric mean sea level and GRACE, J Geod, 86(9): 681-694, doi: 10.1007/s00190-012-1547-6, 2012. Sánchez L.: Towards a vertical datum standardisation under the umbrella of Global Geodetic Observing System. Journal of Geodetic Science 2(4): 325-342, Versita, 10.2478/v10156-012-0002-x, 2012

Sánchez L., Dayoub N., Cunderlík R., Minarechová Z., Mikula K., Vatrt V., Vojtísková M., Síma Z.: W0 estimates in the frame of the GGOS Working Group on Vertical Datum Standardisation. In: Marti U. (Ed.) Gravity, Geoid and Height Systems (GGHS2012), IAG Symposia 141: 203-210, 10.1007/978-3-319-10837-7_26, 2014

Presentations

Sánchez L., Cunderlík R., Dayoub N., Mikula K., Minarechová Z., Síma Z., Vatrt V., Vojtísková M.: Towards a new best estimate for the conventional value of W0. 3rd International Gravity Field Service (IGFS) General Assembly, 2014-07-02

Sánchez L., Dayoub N., Cunderlík R., Mikula K., Minarechová Z., Sí-ma Z., Vatrt V., Vojtíŝková M.: Conventional reference level for a global unified height system. IAG Scientific Assembly, Potsdam, Germany, 2013-09-01

Sánchez L.: Vertical datum standardisation: a fundamental step towards a global vertical reference system. AGU Meeting of the Americas, Cancun, Mexico, 2013-05-16

Sánchez L.: Report on the activities of the Working Group Vertical Datum Standardisation. GGHS 2012, Venice, Italy, 2012-10-09

Sánchez L.: Towards a Vertical Datum Standardisation. AOGS-AGU (WPGM) Joint Assembly, Singapore, 2012-08-14

Sánchez L.: Towards a vertical datum standardisation based on a joint analysis of TIGA, satellite altimetry and gravity field modelling products. IGS Workshop 2012, Olsztyn, Poland, 2012-07-23/27

GGOS Focus Area 2 Geohazards Monitoring

Joint Working Group 0.2.1: 'New Technologies for Disaster Monitoring and Management'

Chair:	Ioannis (John) D. Doukas (Greece)	
Co-Chair:	Günther Retscher (Austria)	
Members:	Jorge Centeno (Brasil)	Melinda Laituri (USA)
	Joseph Dodo (Nigeria)	Jonathan Li (Canada)
	Jacob Ehiorobo (Nigeria)	Beniamino Murgante (Italy)
	Vassilis Gikas (Greece)	Urbano Fra Paleo (Spain)
	Mikhail Kanevski (Switzerland),	Barbara Theilen-Willige (Germany)
Members at Large:	Cheng Wang (China)	Gyula Mentes (Hungary)
	Allison Kealy (USA)	

Purpose and Scope

It is a relatively new group, started on 2011. Goals and purposes: To explore and test any available (or emerging) contemporary technologies that could relate with Disaster Monitoring (DM); to map and register all kinds of disasters, either natural or man-made. The creation of an up-to-date disaster catalogue (typical characteristics, major impacts and other related information etc.), in relation with an up-to-date technologies-catalogue (e.g. benchmark data-sets, hardware, software, methods, algorithms and applications etc.), will form the foundation of the coordination of research and other activities and tasks, as well. Furthermore, the topic is expected to attract a number of interdisciplinary aspects, a fact that will result into most interesting cooperation with a variety of other scientific and/or professional institutes, organizations, groups (including other IAG entities).

Activities and Actions

During the last eight (8) months, the group is under a full reformation process, which will conclude to a new setup, with new members, enrichment of its goals & objectives (by taking into account the rapid changes in the field of geosciences) etc.

Objectives and Planned Efforts for 2015-2017 and Beyond

In the middle of group's reformation, which is expected to finish by the end of the year

Website

http://doukas.civil.auth.gr/iag_sc41_sg41/

Publications and Presentations

Barbara Theilen-Willige and Doukas, I.D.: Remote Sensing and GIS Contribution to the Detection of Areas Susceptible to Earthquake Hazards. The Case Study of Northern Greece. 26th IUGG General Assembly, June 22-July 2, 2015, Prague

GGOS Focus Area 3: Sea-Level Change, Variability and Forecasting

Chair: Tilo Schöne (Germany)
Co-Chair: CK Shum (USA), Mark Tamisiea (UK), Phil Woodworth (UK)

Purpose and Scope

Sea level rise and its impact on human habitats and economic well-being have received considerable attention in recent years by the general public, engineers, and policy makers. A GGOS retreat in 2010 has identified sea level change as one of the cross-disciplinary focus areas for geodesy. Sea Level is also a major aspect in other observing systems, like e.g. GEO or GCOS. The primary focus of GGOS Focus Area 3 (formerly Theme 3) is to demonstrate and apply geodetic techniques, under the umbrella of GGOS, to the possible mitigation or adaption of sea level rise hazards including studies of the impacts of its change over the world's coastal and deltaic regions and islands, and to support practical applications such as sustainability. One major topic is the identification of gaps in geodetic observing techniques and to advocate enhancements to the GGOS monitoring network and Services where necessary.

Activities and Actions

Focus Area 3 has identified actions to be undertaken to advance geodetic techniques and technologies applied to sea level research. These are

- Identification or (re)-definition of the requirements for a proper understanding of global and regional/local sea-level rise and its variability 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, CEOS, and other observing systems).
- Identification of 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.
- Identification of a preliminary set of practical or application (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.

In the long-term, the aim is to support forecasting of global and regional sea level for the 21st century with an expected forecast period of 20 to 30 years or longer.

The Call for Participation (http://www.ggos-portal.org/lang_en/nn_261554/GGOS-Portal/EN/Themes/SeaLevel/seaLevel.html?__nnn=true) was issued in 2012. Special emphasis is given to local and regional projects which are relevant to coastal communities, and which depend on the global perspective of GGOS. Since than three projects have been submitted and are accepted.

Thus, GGOS Focus Area 3 now has three approved "Landmark" projects

- The Use of Continuous GPS and Absolute Gravimetry for Sea Level Science in the UK (NERC British Isles continuous GNSS Facility (BIGF), University of Nottingham, UK), (NERC National Oceanography Centre (NOC), Liverpool, UK)
- Revisiting the Threat of Southeast Asian Relative Sea Level Rise by Multi-Disciplinary Research (Delft University of Technology (DUT), Delft, Netherlands; University of Leeds,

Leeds, United Kingdom; Ecole Normale Supérieure, Paris, France; Chulalongkorn University, Bangkok, Thailand; Royal Netherlands Meteorological Institute (KNMI), De Bilt, Netherlands)

- Bangladesh Delta Relative Sea-Level Rise Hazard Assessment (Division of Geodetic Science, School of Earth Sciences, The Ohio State University, Columbus, Ohio, USA; University of Bonn, Bonn, Germany; GeoForschungsZentrum Potsdam (GFZ), Germany)

Another project may join Focus Area 3:

- Subsidence Monitoring in Urban Areas of the Republic of Indonesia with GNSS-controlled tide gauges and supporting methods (National Geospatial Agency (BIG) of Indonesia; Helmholtz Centre Potsdam GFZ, Germany; Institut Teknologi Bandung, Indonesia)

All projects have their major focus on the combination of sea level and geodetic monitoring in an integrative approach. Focus Area 3 will now work with these projects to carry on actions defined in the Focus Area 3 Action Plan. In addition we are continuing to encourage the development of more proposals.

Also in the reporting period, Focus Area e 3 continued communications with organizations, dealing with other than geodetic aspects of sea level monitoring. These are the UNESCO International Oceanographic Commission Group of Experts (UNESCO/IOC GE) and the World Glacier Monitoring Service (WGMS), and the European COPERNICUS programme. Also cooperation with the IGS Tide Gauge Benchmark Monitoring Working is continued.

A major step for GGOS Focus Area 3 is also the alignment of activities with the GGOS Bureau of Networks and Observations. The improvement of the observation network for sea level research is a major open topic. In 2015, the GLOSS Group of Experts (GLOSS-GE), the IGS TIGA-WG and the GGOS Focus Area 3 has submitted the Report "Priorities for installation of continuous Global Navigation Satellite System (GNSS) near to tide gauges" for consideration by GGOS with its entities and by GIAC.

The GNSS-controlled tide gauges are an important monitoring component in climate and geodetic science. Over the years, the network of collocated stations has been growing, not at least through the constant effort of IOC/GLOSS Group of Experts, the IGS TIGA-WG, and GGOS. The report identifies, under various assumptions, tide gauges, where the community sees a priority need of additional GNSS installations.

Objectives and Planned Efforts for 2015-2017 and Beyond

- Review and Refine current and future aspects of geodetic contributions for sea level research with groups identified in AS-SL-01/AS-SO-02
- Work on to identify and contact emerging Focus Area 3 pilot projects
- Improve discussion with the GGOS Bureau for Networks and Observation about monitoring infrastructure need
- Establish/improve the outreach activities with the help of the GGOS-CO
- Coordinate with GGOS Focus Area 1
- Work with IGS/TIGA on results of the TIGA reprocessing
- Support Focus Area 3 projects
- Work with GGOS and GIAC on the findings of the report "Priorities for installation of continuous Global Navigation Satellite System (GNSS) near to tide gauges"

- Identify geodetic monitoring aspects relevant to Focus Area 3
- Develop and maintain a specific web site for the Focus Area 3 projects

Website

http://www.ggos-portal.org/lang_en/GGOS-Portal/EN/Themes/SeaLevel/seaLevel.html

Publications and Presentations

Pearlman M. R., C. Ma, C. Noll, E.C. Pavlis, H. Schuh, T. Schoene, R Barzaghi, S. Kenyon: The GGOS Bureau of Networks and Observations and an Update on the Space Geodesy Networks, (http://meetingorganizer.copernicus.org/EGU2015/EGU2015-7420.pdf). 2015

Schöne, T., CK. Shum, M. Tamisiea, P. Woodworth: GGOS Theme 3: Understanding and Forecasting Sea-Level Rise and Variability, OSTST2014, Ocean Surface Topography Science Team Meeting, Lake Constance, Germany, October 2014 (http://www.ostst-altimetry-2014.com/wp-content/uploads/abstracts_books-OSTST_141027.pdf), 2014

Schöne, T., CK. Shum, M. Tamisiea, P. Woodworth: GGOS Theme 3: Understanding and Forecasting Sea-Level Rise and Variability, International Association of Geodesy Scientific Assembly, 150th Anniversary of the IAG, Potsdam, 1.-6. Sep.2013, http://www.iag2013.org/IAG_2013/Welcome_files/abstracts_iag_2013_2808.pdf, 2013

Schöne, Shum, Tamisea, Woodworth: Theme 3: Sea-Level Change, Variability and Forecasting, Report of the International Association of Geodesy 2011-2013 ─ Travaux de l'Association Internationale de Géodésie 2011-2013, http://iag.dgfi.badw.de/fileadmin/IAG-docs/Travaux2013/07_GGOS.pdf, page 31-32, 2013

Merrifield, Mark, Simon Holgate, Gary Mitchum, Begoña Pérez, Lesley Rickards, Tilo Schöne, Philip Woodworth and Guy Wöppelmann, Thorkild Aarup: Global Sea Level Observing System (GLOSS) Implementation Plan – 2012, UNESCO/IOC, 41pp. 2012. (IOC Technical Series No. 100), http://www.unesco.org/ulis/cgi-bin/ulis.pl?catno=217832&set=50929BE4_3_465&gp=1&lin=1&ll=1, 2012