Commission 1 – Reference Frames

President: **Geoffrey Blewitt** (USA)
Vice President: **Johannes Böhm** (Austria)

http://iag.geo.tuwien.ac.at/c1/

Terms of Reference

Reference systems and frames are of primary importance for much Earth science based research and applications, satellite navigation as well as for practical applications in geo-information. A precisely defined reference frame is needed for an improved understanding of the Earth's rotation and its gravity field, sea level change with time, tectonic plate motion and deformation, glacial isostatic adjustment, geocentre motion, deformation due to Earthquakes, local subsidence and other crustal displacements. Commission 1 activities and objectives deal with the theoretical aspects of how best to define reference systems and how reference systems can be used for practical and scientific applications. Commission 1 will closely interact with the other IAG Commissions, ICCT, Services and GGOS components where reference system aspects are of concern. Commission 1 is identical with Sub-commission B2 of COSPAR.

Objectives

- Definition, establishment, maintenance and improvement of the geodetic reference frames;
- Advanced terrestrial and space observation technique development for the above purposes;
- International collaboration for the definition and deployment of networks of terrestrially-based space geodetic observatories;
- Theory and coordination of astrometric observation for reference frame purposes.
- Collaboration with space geodesy/reference frame related international services, agencies and organizations;
- Promote the definition and establishment of vertical reference systems at global level, considering the advances in the regional sub-commissions;
- Work to maintain a reference frame that is valuable for global change studies

Structure

Sub-Commissions

SC 1.1: Coordination of Space Techniques
Chair: Urs Hugentobler (Germany)

SC 1.2: Global Reference Frames
Chair: Xavier Collilieux (France)

SC 1.3: Regional Reference Frames
Chair: Carine Bruyninx (Belgium)
SC 1.3a: Europe
Chair: Markku Poutanen (Finland)
SC 1.3b: South and Central America
Chair: William Martinez (Colombia)
SC 1.3c: North America
Chair: Michael Craymer (Canada)
SC 1.3d: Africa
Chair: Elifuraha Saria (Tanzania)
SC 1.3e: Asia-Pacific
Chair: John Dawson (Australia)
SC 1.3f: Antarctica
Chair: Martin Horwath (Germany)

SC 1.4: Interaction of Celestial and Terrestrial Reference Frames
Chair: Zinovy. Malkin (Russia)

Joint Study Groups

JSG 0.22: Definition of Next Generation Terrestrial Reference Frames
(joint with ICCT, description see ICCT)
Chair: Christopher Kotsakis (Greece)

JSG 3.1: Intercomparison of Gravity and Height Changes
(joint with IGFS, Commissions 2 and 3, description see Commission 3)
Chair: Severine Rosat (France)

Joint Working Groups

JWG 0.1.2: Strategy for the Realization of the International Height Reference System (IHRS)
(joint with GGOS, Commission 2 and IGFS, description see GGOS)
Chair: Laura Sanchez (Germany)

JWG 1.1: Site Survey and Co-location
(joint with the IERS)
Chair: Sten Bergstrand (Sweden)

JWG 1.2: Modelling Environmental Loading Effects for Reference Frame Realizations
(joint with the IERS)
Chair: Tonie van Dam (Luxembourg)

JWG 1.3: Troposphere Ties
(joint with Commission 4)
Chair: Robert Heinkelmann (Germany)

JWG 2.1: Relativistic Geodesy: First Steps Towards a New Geodetic Technique
(joint with Commission 2, description see Commission 2)
Chair: Jakob Flury (Germany)

JWG 3.2: Constraining Vertical Land Motion of Tide Gauges
(joint with Commission 3, description see Commission 3)
Chair: Alvaro Santamaría-Gómez (France)

Program of Activities

The program of activities for Commission 1 includes:

- Theoretical and applied research activities related to reference frames;
- Research and development activities that impact the reference frame determination and its accuracy, as well as, the best and optimal usage of reference frames in Earth Science applications;
- Interaction with all established IAG Services: IVS, IGS, ILRS, IDS and the IERS, including their Combination Centres and Working Groups;
- Development in the theory and application of the transformation between Celestial and Terrestrial Reference Systems and application of the theory to improve the consistency between ICRF, ITRF and EOPs, in cooperation with IVS and IERS;
- Exploration of advanced methodologies for the combination of products and raw observations of space geodetic techniques;
- Investigation of systematic error sources and factors limiting the precision of space geodetic techniques and their combination;
- Encouraging and assisting regional sub-commission countries to re-define and modernize their national geodetic systems so that they are compatible with the ITRF;
- Establishment of a dedicated Web site relating all Commission 1 activities.

Steering Committee

President Commission 1:	Geoffrey Blewitt (USA)
Vice President Comm. 1:	Johannes Böhm (Austria)
Chair Sub-Comm. 1.1:	Urs Hugentobler (Germany)
Chair Sub-Comm. 1.2:	Xavier Collilieux (France)
Chair Sub-Comm. 1.3:	Carine Bruyninx (Belgium)
Chair Sub-Comm. 1.4:	Zinovy Malkin (Russia)
Representative of IERS:	Detlef Angermann (Germany)
Representative of ILRS:	Vincenza Luceri (Italy)
Representative of IVS:	Guangli Wang (China)
Member-at-Large:	Gary Johnston (Australia)

Sub-Commissions

SC 1.1: Coordination of Space Techniques

Chair: Urs Hugentobler (Germany)

Terms of Reference

Space techniques play a fundamental role for the realization and dissemination of highly accurate and long term stable terrestrial and celestial reference frames as well as for accurate monitoring of the Earth orientation parameters linking the two fundamental frames. The current space geodetic techniques contributing to ITRF and ICRF, i.e., Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Global Navigation Satellite Systems (GNSS) and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) have particular strengths and technique-specific weaknesses.

Strengths of the techniques are exploited by combining them making use of fundamental sites co-locating more than one technique. Sub-commission 1.1 focusses on the coordination of research related to the geodetic space techniques with emphasis on co-location aspects at fundamental geodetic observatories as well as on co-location targets in space, considering common parameters such as coordinates of stations and satellites, troposphere parameters, and clock parameters.

Objectives

- Coordinate research on co-location using common parameters in space;
- Coordinate research on co-location using common parameters at fundamental geodetic observatories;
- Explore the use of new techniques and technologies;
- Interface with IERS WG on Site Survey and Co-location;
- Interface with the GGOS Committee on Performance Simulations and Architectural Trade-Offs (PLATO);
- Interface with Joint WG on Tropospheric Ties.

Working Groups of Sub-Commission 1.1

WG 1.1.1: Co-Location using Clocks and New Sensors

Chair: Ulrich Schreiber (Germany)

Terms of Reference

The establishment of accurate local ties of different space geodetic techniques at fundamental geodetic observatories poses a long-standing problem. While geometric ties can be determined at sub-millimeter-level, the relation to physical phase centers of the instruments and temporal stability of such offsets are usually known with significantly lower precision. Novel ways for inter-technique calibration at a geodetic site need to be developed using existing and new sensors and technologies, such as highly accurate time and frequency transfer, ultra-stable clocks, and co-location targets. Complementary to such development the tying of techniques shall be exploited to their limits at the analysis level e.g. to using common clock and troposphere parameters.

Objectives

The main objective of the working group is the investigation of new methods and technologies to cross-calibrate space geodetic sensors at geodetic observatories and to exploit common parameters at the analysis level. The working group will

- Investigate new technologies for inter-technique calibration of sensors at geodetic observatories;
- Investigate the capabilities of accurate time and frequency distribution between sensors at geodetic observatories and between observatories;
- Investigate the long-standing discrepancy in scale coming from VLBI and SLR;
- Address the use of new sensors such as ring lasers, quantum sensors, etc.;
- Further assess the contribution of estimation of common parameters at analysis level to the stability and accuracy of geometric local ties and the consistency of combined global reference frames.

To this purpose it closely interacts with the IERS WG on Site Survey and Co-location and the Joint WG 1.1.6 on Tropospheric Ties.

JWG 1.1.2: Performance Simulations and Architectural Trade-Offs (PLATO)
(joint with GGOS)

Chair: Daniela Thaller (Germany)
Vice-chair: Benjamin Männel (Germany)

Terms of Reference

The terrestrial reference frame (TRF) is the foundation for virtually all space-based and ground-based Earth observations. Positions of objects are determined within an underlying TRF and the accuracy with which objects can be positioned ultimately depends on the accuracy of the reference frame. The most accurate and stable global TRFs currently available are the "International Terrestrial Reference Frames (ITRFs)" produced under the auspices of the "International Earth Rotation and Reference Systems Service (IERS)" in cooperation with its technique-specific services IDS, IGS, ILRS and IVS. In order to meet the anticipated future needs of science and society, GGOS has determined that by 2020 the accuracy and stability of the ITRF needs to be better than 1mm and 0.1mm/y, respectively. The current ITRF is at least an order of magnitude less accurate and stable than these goals.

The ITRF is currently determined and maintained by a subset of ground-based observations acquired by the space-geodetic measurement techniques of VLBI, SLR, GNSS, and DORIS. Further improvements of the ITRF are thought to be achieved by:

- Developing next generation space-geodetic stations with improved technology and system performance;
- Improving the ground network configuration in view of global coverage and co-locations;
- Improving the number and accuracy of surveys between co-located stations;
- Deploying, improving and optimizing space-based co-locations.

This joint working group aids these activities and helps to evaluate the impact on the accuracy and stability of future ITRFs.

Objectives

Several aspects related to design of ground- and space-based architectures and their impact on TRF accuracy and stability are investigated:

- Study different ground station architectures and possible evolutions (different techniques, mix of legacy and next generation stations, co-located sites, data improvements/ degradations, etc.);
- Develop optimal methods of deploying next generation stations for TRF computation
- Study requirements on site ties and space ties, including trade-offs between co-locating techniques on ground and/or in space;
- Study different space-based architectures, including laser ranging to GNSS or LEO satellites, VLBI observations to GNSS satellites;
- Study new concepts for space-based architectures (including inter-satellite links, specially designed co-location satellites, VLBI transmitter on the moon, etc.);
- Study evolution of space-based architectures (including degradation of laser ranging targets, additional targets, new satellites / constellations, etc.);
- Study trade-offs in space-geodetic data, e.g., between number of stations vs. accuracy of observations, and co-locating techniques at all sites vs. co-locating some techniques at some sites, and number of co-located satellites vs. amount of observations per space co-location.

These and other related aspects will be addressed by two types of approaches:

- Develop improved analysis methods using all existing data and co-locations;
- Carry out simulations for future improvements and optimization of ground network, space segment and observation scenario.

SC 1.2: Global Reference Frames

Chair: Xavier Collilieux (France)

Terms of Reference

Global reference frames are fundamental to study and locate global phenomena or objects at the Earth's surface, in the ocean or in space, and to determine Earth's rotation in space. Sub-commission 1.2 focuses its activity on the definition and realization of the terrestrial reference system (TRS) and its link to world height system (WHS). It shall study fundamental questions but also more practical aspects that could improve current terrestrial reference frame (TRF) determinations.

More than 35 years of space geodetic observations are now available. Thanks to this extraordinary datasets, non-stationary Earth surface displacements are now clearly evidenced. The next generation of TRF should be able to explicitly model them or should be constructed in such a way that those displacements do not affect its accuracy. Time series of frames have been suggested in the past as a potential solution but practical issues still need to be coped with so that the implicit reference frame reach the required accuracy. Multi-technique satellite that should tie all kind of space geodetic could potentially solve most of these practical issues. However, a set of accurate tie vectors that relates position of various technique instruments at co-location sites will still be of outmost importance to validate those new ties and monitor their variations along time. Work on enhanced parametric modeling, coupled with enhanced forward displacement model is an alternative to TRF time series. This approach is in agreement with past modeling of the International Terrestrial Reference Frame (ITRF) but still require progress in forward models (loading, seismic). In parallel of this work on the TRF modeling, study of systematic errors in the coordinates provided by various techniques is still mandatory to improve the homogeneity and frame definition of the TRF whatever the solution that will be adopted.

A step forward could be established by investigating relativistic reference frames based on a network of clocks in space linked with time transfer technologies. Such realized frame would be entirely decoupled from ground fixed stations and could be used to reference any point on the Earth's surface. Difference of frequencies of clocks would inform on Earth gravity potential differences, this technology being used in the end to determine a world height system based on a network of ground clocks. In such a framework, distinction between geometric and gravity based height system disappears.

While this ultimate goal still requires intensive research works, TRF and future WHS need to be studied in closer partnership in order to locate reference benchmarks, gravimeters or clocks in the TRF but also to provide consistent coordinate and altitude time-variations.

The work of this sub-commission will be done in partnership with the International Earth Rotation and Reference Systems Service (IERS), IAG commission 2 and Inter-Commission Committee on Theory (ICCT) as well as IAG Global Geodetic Observing System (GGOS). Cooperation with International Astronomical Union (IAU) and International Organization for standardization (ISO) will be also continued.

Objectives

The main objectives of sub-commission 1.2 are the following:

- Standardization activities: ISO, United Nations Committee of experts on Global Geospatial Information Management (UN-GGIM) working group on global geodetic reference frame (GGRF), IERS conventions;
- Definition of the global terrestrial reference frame (origin, scale and orientation, time evolution, standards, conventions, models);
- Enhanced forward modeling of the Earth’s deformation;
- Modeling of the reference frame in general relativity;
- Linking global height system with the terrestrial reference frame;
- Evaluation of systematic errors by focusing on errors at co-location sites and offset detection methods;
- Methods to determine local tie vectors;
- Impact of multi-technique satellites (space ties).

Links to Services

Sub-Commission 1.2 will establish close links to the relevant services for reference frames, namely the IERS, GGOS and IAG technique services: International GPS Service (IGS), International Laser Ranging Service (ILRS), International VLBI Service for Geodesy and Astrometry (IVS), and International DORIS Service (IDS).

Working Groups of Sub-Commission 1.2

WG 1.2.1: Offset Detection in Geodetic Coordinate Time Series

Chair: Simon Williams (UK)

Terms of Reference

The accuracy and validity of geodetic positioning time series are often degraded by the presence of step discontinuities (offsets) that may either be known (e.g. documented equipment changes or earthquakes) or unknown, and with amplitudes that are, at best, known imprecisely. Undetected offsets can have an adverse effect on estimated velocities. Accurate velocities are required for many geophysical studies such as plate tectonics, intra-plate deformations, global reference frames and regional and global sea level. For example vertical land movements at tide gauges need to be obtained with a precision and accuracy of 0.1-0.2 mm/yr for sea level change studies. As the length of time series continue to increase the number of offsets is likely also to increase and the cumulative effect of even the smallest of offsets can seriously alter our velocity estimates. This, coupled with the huge growth in the number of sites, particularly GNSS, necessitates the automation of site velocity estimation and therefore offset detection. Offset detection is an issue in many different scientific studies, where it is often called data segmentation or homogenization, such as climate/meteorology, economics, image processing and bio-statistics. However what works in one discipline may not be suitable in another. The aim of this working group is to encourage cooperation between different groups in the geodetic community to contribute, investigate and disseminate different offset detection methods and provide a realistic benchmark dataset(s) on which to test their efficacy.

Objectives

- Encourage cooperation between different groups in the geodetic community to contribute, investigate and disseminate different offset detection methods;
- Identify and provide offset detection methods for the use of the community, including code;
- Provide a realistic benchmark dataset(s) on which to test their efficacy (successor to the DOGEx);
- Evaluate the validity of alternative velocity estimation methods that may be less biased by undetected offsets particularly in the context of a DOGEx follow on;
- Provide guidelines and advice on offset detection in geodetic coordinate time series;
- Foster and establish interactions with other areas of science for which offset detection is also an issue to identify different approaches to the problem.

Members

Simon Williams (UK), Chair
Machiel Bos (Portugal)
Norman Teferle (Luxembourg)
Matt King (Australia)
Xavier Collilieux (France)
Jarir Saleh (USA)

SC 1.3: Regional Reference Frames

Chair: Carine Bruyninx (Belgium)

Terms of Reference

Sub-commission 1.3 deals with the definitions and realizations of regional reference frames and their connection to the global International Terrestrial Reference Frame (ITRF). It offers a home for service-like activities addressing theoretical and technical key common issues of interest to regional organisations.

Objectives

In addition to the specific objectives of each regional Sub-commission, the main objectives of SC 1.3 as a whole are to:

- Coordinate the activities of the regional Sub-commissions focusing on exchange of data, competences and results;
- Promote operation of permanent GNSS stations, in connection with IGS whenever appropriate, as the basis for the long-term maintenance of regional reference frames;
- Promote open access to the GNSS data from permanent GNSS stations used for the maintenance of regional reference frames and scientific applications;
- Develop specifications for the definition and realization of regional reference frames, including the vertical component with a special consideration of gravity and other data;
- Encourage and stimulate the development of the AFREF project in close cooperation with IGS and other interested organizations;
- Encourage and assist countries, within each regional Sub-commission, to re-define and modernize their national geodetic systems, compatible with the ITRF;
- Support the initiatives of the GGRF (Global Geodetic Reference Frame) WG of the UN-GGIM (United Nations Initiative on Global Geospatial Information Management).

Program of Activities

- Organize inter-regional workshops addressing activities, results and key issues of common interest to the regional Sub-commissions;
- Develop analysis strategies and compare methods for the implementation of the regional reference frames and their expression in the ITRF, in full interaction with the IGS;
- Consider developing tectonic deformation models that will enable transformation of locations within a defined reference frame between different epochs;
- At regional levels, contribute to the realization and improvement of local surveys in the collocation sites, with full cooperation with the Sub-Commission 1.2 Global Reference Frames.

SC 1.3a: Europe

Chair: Markku Poutanen (Finland)
Secretary: Wolfgang Söhne (Germany)

Terms of Reference

EUREF, the Regional Reference Frame Sub-commission for Europe, deals with the definition, realization and maintenance of the European Reference Frames. EUREF is focusing on both the spatial and the vertical components in close cooperation with the pertinent IAG components (Services, Commissions, and Inter-commission projects) and EuroGeographics, the consortium of the National Mapping and Cadastral Agencies (NMCA) in Europe. For more information, see www.euref.eu.

Objectives

EUREF's objectives are

- The definition, realization and maintenance of the European Geodetic Reference Systems;
- The promotion and assistance of the adoption and use of European Terrestrial Reference System (ETRS89) and European Vertical Reference System (EVRS) in our partner countries;
- The development and maintenance of the EUREF GNSS Permanent Network (EPN) which is the ground based GNSS infrastructure for scientific and practical applications in positioning and navigation (GGOS, IGS Real-time Service);
- The development of strategies and technologies for the realization of geodetic reference systems.

Structure

EUREF is composed of representatives from European IAG member countries.

The TWG (Technical Working Group) is composed of members elected by the plenary, members in charge of special tasks and ex-officio members.

Program of Activities

- Continue to develop the EPN in close cooperation with IGS (International GNSS Service), for the maintenance of the European Terrestrial Reference Frame (ETRF), as a contribution to the ITRF and as an infrastructure to support practical applications for precise positioning and referencing geo-information;
- Extend the Unified European Levelling Network (UELN) and prepare it to be computed under a geokinematic approach using the European Combined Geodetic Network (ECGN) for a long-term maintenance of the European Vertical Reference Frame (EVRF);
- Support new developments in reference frame realization and application by introducing new technologies like real-time GNSS data transfer and products, as well as Galileo for precise positioning;
- Realize a dense and homogeneous position and velocity product for Europe;
- Establish a dense velocity field model in Europe for the long-term maintenance of the European reference frame;
- Cooperate with European political and scientific organisations and projects, e.g. EuroGeographics, EUMETNET, CEGRN (Central European GPS Geodynamic Reference Network), EPOS (European Plate Observing System), UN-GGIM: Europe, etc.
- Consider the contribution to the IAG Programme GGOS (Global Geodetic Observing System) using the installed infrastructures managed by the EUREF members;
- Promote the adoption of the reference systems defined by EUREF (ETRS89-European Terrestrial Reference System 1989 and EVRS - European Vertical Reference System) in the European countries and European-wide initiatives related to geo-referencing activities like INSPIRE;
- Organize annual symposia addressing activities carried out at national and Europe-wide levels related to the global work and objectives of EUREF.

SC 1.3b: South and Central America

Chair: William Martinez (Colombia)
Vice-chair: Virginia Mackern (Argentina)

Terms of Reference

Sub-commission 1.3b (South and Central America) encompasses the activities developed by the "Geocentric Reference System for the Americas" (SIRGAS). As such, it is concerned with the definition, realization and maintenance of a modern geodetic reference infrastructure for South and Central America and the Caribbean. This includes a geometric reference frame consistent with ITRS/ITRF and a gravity field-related vertical reference system, defined and realized globally.

Objectives

The main purposes of the Sub-commission 1.3b are:

- To determine, maintain and make available a geocentric reference frame (a set of stations with high-precise geocentric positions and their variation with time, as a regional densification of the global ITRF);
- To support the SIRGAS countries in the establishment and maintenance of national reference networks as local densifications of SIRGAS in order to guarantee accessibility to the ITRF at national and local levels;
- To establish a unified vertical reference system supporting the determination and precise combination of physical and geometric heights as well as their variations with time;
- To contribute to the GGOS program by developing and implementing state-of-the-art products based on the SIRGAS observational infrastructure;
- To promote, support, and coordinate the efforts of the Latin American and Caribbean countries to achieve these objectives.

Structure

The structure of the Sub-commission 1.3b is based on the functioning bodies of SIRGAS. There are currently three Working Groups:

- WG 1.3b.1: Reference System
  Chair : Víctor José Cioce (Venezuela)
- WG 1.3b.2: SIRGAS at National Level
  Chair: Roberto Pérez Rodino (Uruguay)
- WG 1.3b.3: Vertical Datum
  Chair : Silvio Rogério Correia de Freitas (Brazil)

The SIRGAS Executive Committee (as it is named in the SIRGAS statutes) is composed of:

- SC1.3b Chair : W. Martínez (Colombia)
- SC1.3b Vice-chair : Virginia Mackern (Argentina)
- SC1.3b WG1 Chair : Víctor José Cioce (Venezuela)
- SC1.3b WG2 Chair : Roberto Pérez Rodino (Uruguay)
- SC1.3b WG3 Chair : Silvio Correia de Freitas (Brazil)

Program of Activities

Since the SIRGAS countries are improving their national reference frames by installing an increasing number of continuously operating GNSS stations, it is necessary to outline the best strategy for the appropriate integration of those frames into the continental frame. This includes:

- Promotion of the IGS and IERS standards within the SIRGAS countries to ensure the adequate installation, maintenance, and analysis of continuously operating GNSS stations;
- Establishment of a SIRGAS National Processing Centre in all the member countries;
- Refinement of the SIRGAS station hierarchy. At present, two classes are considered: core and densification stations (the establishment of other categories is under consideration);
- Promotion of the adequate usage of SIRGAS as a reference frame by means of capacity building. This comprises SIRGAS schools on reference frames, scientific processing of GNSS data, atmospheric analysis based on the SIRGAS infrastructure, etc.;
- Promotion and implementation of real-time services based on the SIRGAS infrastructure to make available the reference frame to more users;
- The kinematics of the SIRGAS frame, up to now, have been represented by linear station movements (i.e. constant velocities). This representation is not sufficiently precise due to existing seasonal variations in the station position time series and due to discontinuities caused by the frequent occurrence of seismic events in the SIRGAS region.

According to this, it is necessary:

- To model non-linear station movements within the reference frame computation;
- To implement a methodology aiming at a precise transformation between different epochs and, in general, between pre-seismic and post-seismic reference frame realizations in particular;
- To evaluate the feasibility of computing and using near-real time reference frames instead of those based on epoch station positions and constant velocities.

The establishment of a unified vertical reference system continues to be a big challenge of SIRGAS. The related activities concentrate on:

- Continental adjustment of the national vertical networks in terms of geo-potential numbers;
- Combined analysis of tide gauge registrations, GNSS positioning and satellite altimetry observations to determine the dynamic ocean topography at the classical vertical datums;
- Determination of potential differences between the reference tide gauges and the global reference surface;
- Stronger cooperation with the Sub-Commission 2.4b (Gravity and Geoid in South and Central America - GGSCA) to promote national initiatives regarding the modernization of the gravity reference networks and the computation of geoid models of high resolution.

Hourly SIRGAS ionospheric models (vTEC) based on the GNSS SIRGAS stations have been generated since 2006 on a regular basis. The SIRGAS ionospheric model is being upgraded to include a better distribution of the electron density based on the assimilation of ground- and space-based GNSS observations. In addition, SIRGAS is developing a service for computing water vapour estimations.

SC 1.3c: North America

Chair: Michael Craymer (Canada)
Vice-chair: Dan Roman (USA)

Terms of Reference

To provide international focus and cooperation for issues involving the horizontal, vertical, and three-dimensional geodetic control networks of North America, including Central America, the Caribbean and Greenland (Denmark). For more information, see www.naref.org.

Objectives

In collaboration with the IAG community, its service organisations and the national geodetic organizations of North America, the aims and objectives of this regional Sub-commission are to provide international focus and cooperation for issues involving the horizontal, vertical and three dimensional geodetic control networks of North America. Some of these issues include:

- Densification of the ITRF reference frame in North America and the promotion of its use;
- Maintenance and future evolution of plate-fixed geometric reference frames for North America, including the North American Datum of 1983 (NAD83) and any possible successors.
- Maintenance and future evolution of vertical datums (ellipsoidal and orthometric), including the North American Vertical Datum of 1988 (NAVD88) and the International Great Lakes Datum (IGLD);
- Effects of crustal motion, including post-glacial rebound and tectonic motions along, e.g., the western coast of North America and in the Caribbean;
- Standards for the accuracy of geodetic positions;
- Outreach to the general public through focused symposia, articles, workshops and lectures, and technology transfer to other groups.

Structure

Chair: Michael Craymer (Canada)
Vice-chair: Dan Roman (USA)

Organizing Committee:
Michael Craymer (Canada), Dan Roman (USA), Bo Finn Madsen (Denmark), Guido Gonzalez (Mexico)

Working Groups of Sub-Commission 1.3c

WG 1.3c.1: North American Reference Frame (NAREF)

Chair: Michael Craymer (Canada)

Programme of Activities

To densify the ITRF reference frame in the North American region by organizing the computation of weekly coordinate solutions and associated accuracy information for continuously operating GPS stations that are not part of the current IGS global network. A cumulative solution of coordinate and velocities will also be determined on a weekly basis. The working group will organize, collect, analyse and combine solutions from individual agencies, and archive and disseminate the weekly and cumulative solutions.

WG 1.3c.2: Plate-Fixed North American Reference Frame

Chair: TBD (USA)

Programme of Activities

To establish a high-accuracy, geocentric reference frame, including velocity models, procedures and transformations, tied to the stable part of the North American tectonic plate which would replace NAD83 and serve the broad scientific and geomatics communities by providing a consistent, mm-accuracy, stable reference with which scientific and geomatics results (e.g., positioning in tectonically active areas) can be produced and compared.

WG 1.3c.3: Reference Frame Transformations

Chair: Michael Craymer (Canada)

To determine consistent relationships between international, regional and national reference frames/datums in North America, to maintain (update) these relationships as needed and to provide tools for implementing these relationships.

SC 1.3d: Africa

Chair: Elifuraha Saria (Tanzania)

Terms of Reference

Sub-commission 1.3d (Africa) is concerned with the definition and realization of a unified continental reference frame (AFREF) for Africa, which will be consistent and homogeneous with the global International Terrestrial Reference Frame (ITRF).

Objectives

In collaboration with the IAG community and its services organisations and the National and Regional Mapping Organisations of Africa, the aims and objectives of Sub-commission 1.3d (Africa) are:

- To define the continental reference system of Africa. The goal is to establish and maintain a unified geodetic reference network as the fundamental basis for the national 3-D reference networks fully consistent and homogeneous with the global reference frame of the ITRF;
- To realize a unified vertical datum and support efforts to establish a precise African geoid, in concert with the African Geoid project (Project 2.3 in Commission 2) activities;
- To establish continuous, permanent GNSS stations such that each nation or each user has free access to, and is at most 500km from, such stations;
- To provide a sustainable development environment for technology transfer, so that these activities will enhance the national networks, and numerous applications, with readily available technology;
- To understand the necessary geodetic requirements of participating national and international agencies and;
- To assist in establishing in-country expertise for implementation, operations, processing and analyses of modern geodetic techniques, primarily GNSS.

Program of Activities

It is envisaged that the regionalization of AFREF will follow an approach that consists of three major phases:

- The establishment of a framework of permanent or semi-permanent GPS base stations throughout the region that will become part of the worldwide IGS stations network;
- The densification of the network of permanent or semi-permanent base stations, largely on a country-by-country basis, to determine the relationship between the national geodetic system and the ITRS, and to refine the transformation parameters necessary to relate the national systems to a common ITRF;
- The third and equally important phase of the project will be to address the development of a more refined geoid model for Africa and the definition of a common vertical datum for the continent. This will be done in collaboration with the IAG Africa Geoid Project.

It is further planned to hold workshops and seminars to strengthen the science and knowledge of geodesy and GNSS within Africa and their application to the development of reference frames.

SC 1.3e: Asia-Pacific

Chair: John Dawson (Australia)

Terms of Reference

To improve regional cooperation that supports the realization and densification of the International Terrestrial Reference frame (ITRF). This activity will be carried out in close collaboration with the Geodetic Reference Framework for Sustainable Development Working Group of the United Nations Global Geospatial Information Management for Asia and the Pacific (UN-GGIM-AP).

Objectives

The objectives of the Sub-commission 1.3e are:

- The densification of the ITRF and promotion of its use in the Asia Pacific region;
- To encourage the sharing of GNSS data from Continuously Operating Reference Stations (CORS) in the region;
- To develop a better understanding of crustal motion in the region;
- To promote the collocation of different measurement techniques, such as GPS, VLBI, SLR, DORIS and tide gauges, and the maintenance of precise local geodetic ties at these sites; and
- To outreach to developing countries through symposia, workshops, training courses, and technology transfer activities.

Program of Activities

The activities of this Sub-commission will principally be those of the Asia-Pacific Reference Frame (APREF), see http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/asia-pacific-reference-frame.

SC 1.3f: Antarctica

Chair: Martin Horwath (Germany)

Terms of Reference

Sub-commission 1.3f (Antarctica) focuses on the realization and densification of a unified reference frame for Antarctica, which will be consistent with the global International Terrestrial Reference Frame (ITRF).
The Sub-commission shares objectives and activities of the Scientific Committee on Antarctic Research (SCAR), namely of the SCAR Expert Group Geodetic Infrastructure for Antarctica (GIANT). The Sub-commission closely links IAG and SCAR activities by embedding identical activities, with identical persons where indicated, into the two complementary organisational structures.

Objectives

- Maintenance and densification of the precise geodetic reference network in Antarctica by permanent observations and GNSS campaigns;
- Realization of a unified vertical datum including GNSS ties of tide gauges;
- Providing unified reference for further GNSS applications like airborne gravimetry, ground truthing for satellite missions, geodynamics and glaciology;
- Develop technologies for remote geodetic observatories.
- Stimulate and coordinate international collaboration on the above fields, under the unique political conditions of Antarctic research given by the Antarctic Treaty, in order to make optimum use of logistics and infrastructure.

Program of Activities

- Organization of GNSS campaigns in Antarctica;
- Extend activities for the operation of remote permanent GNSS stations;
- Maintenance of the data archive (SCAR GNSS data base) to collect Antarctic GNSS data and provide them to the scientific community;
- Data analysis and determination of the Antarctic GNSS network as a regional densification of ITRF;
- Provide homogeneous site velocities for e.g. glacial isostatic adjustment determination;
- Support airborne surveys and satellite missions with precise terrestrial reference;
- Collaborate with IAG Sub-Commission 3.4 (Cryospheric Deformation) and the SCAR Scientific Research Programme Solid Earth Response and influence on Cryosphere Evolution (SERCE)
- Organize special workshop(s) on the consistent analysis of GNSS data and realization of ITRF
- Organize meetings/sessions at conferences like IAG, IUGG, SCAR Open Science Conference.

Working Groups of Sub-Commission 1.3

WG 1.3.1: Time-Dependent Transformations Between Reference Frames

Chair: Richard Stanaway (Australia)

Terms of Reference

The main aim of the WG is to focus research in deformation modelling into the rapidly emerging field of regional reference frames used in applied geodesy, particularly positioning and GIS. Deformation models and other time-dependent transformation models provide linkages between global reference frames such as ITRF, regional reference frames and local reference frames commonly used for land surveying and mapping.

The WG will integrate the findings of IAG WG 1.3.1 "Integration of dense velocity fields in the ITRF" (2011-2015), the EUREF WG on Deformation Models and other current research into developing a global deformation and transformation model schema that can be used to support realisation of regional and local reference frames from ITRF to support GIS and positioning technologies such as Network RTK (NRTK). This will require development of a standardised deformation model format that can be accessed from international registries of geodetic parameters such as those hosted by ISO/TC 211 and EPSG (European Petroleum Survey Group).

WG 1.3.1 will work closely with FIG Commission 5 (Positioning and Measurement), specifically FIG Working Group 5.2 (Reference Frames). WG members comprise of a wide spectrum of researchers from different fields of geophysics, geodesy, land surveying and GIS.

Members

Richard Stanaway (Australia), Chair
Hasanuddin Abidin (Indonesia)
Sonia Alves (Brazil)
Graeme Blick (New Zealand)
Miltiadis Chatzinikos (Greece)
Chris Crook (New Zealand)
Paul Denys (New Zealand)
Nic Donnelly (New Zealand)
Rui Fernandes (Portugal)
Yasushi Harada (Japan)
Kevin Kelly (USA)
Juliette Legrand (Belgium)
Daphné Lercier (France)
Martin Lidberg (Sweden)
Rob McCaffrey (USA)
Christopher Pearson (New Zealand)
Craig Roberts (Australia)
Laura Sánchez(Germany)
Yoshiyuki (Japan)
Norman Teferle (Luxembourg)

SC 1.4: Interaction of Celestial and Terrestrial Reference Frames

Chair: Zinovy Malkin (Russia)

Terms of Reference

International terrestrial and celestial reference frames, ITRF and ICRF, respectively, as well as the tie between them expressed by the Earth Orientation parameters (EOP) are key products of geodesy and astrometry. The requirements to all the components of this triad grow steadily and the mm/μas level of accuracy is the current goal of the astronomic and geodetic community.

The current computation procedures for ITRF and ICRF are based on multi-stage processing of observations made with several space geodetic techniques: VLBI, SLR, GNSS, and DORIS. Not all of them provide equal contributions to the final products. The latest ITRF realizations have been derived from combination of normal equations obtained from all four techniques, whereas the ICRF is a result of a single global VLBI solution. The latter is tied to the ITRF using an arbitrary set of reference stations. But VLBI relies on the ITRF origin provided by satellite techniques and shares responsibility with SLR for the ITRF scale. And all the techniques contribute to positions and velocities of ITRF stations.

This situation causes complicated mutual impact of ITRF and ICRF, which should be carefully investigated in order to improve the accuracy of both reference systems and the consistency between each other and EOP. The subject becomes more and more complicated when moving to millimeter accuracy in all components of this fundamental triad. As a consequence, we face systematic errors involving the connection between the ICRF and ITRF realizations, which cannot be fixed by datum correction during the current solution.

Objectives

There are several issues currently preventing the realization of the terrestrial and celestial reference systems (TRF and CRF, respectively) at the mm/μas level of accuracy:

- Insufficient number and non-optimal distribution of active and stable (systematically and physically) stations (VLBI and SLR in the first place) and radio sources;
- Technological (precision) limitations of existing techniques;
- Incompleteness of the theory and models;
- Not fully understood and agreed-upon details of the processing strategy.

These issues are the subject of research of the IAG Sub-Commission 1.4. The SC 1.4 is organized in three Working Groups in close cooperation.

Working Groups of Sub-Commission 1.4

WG 1.4.1: Consistent Realization of ITRF, ICRF, and EOP

Chair: Manuela Seitz (Germany)

Objectives

- Investigation of the impact of different analysis options and combination strategies on the consistency between TRF, CRF, and EOP derived from joint analysis of the space geodesy observations.
- Investigation of the consistency between the current ICRF and ITRF versions and IERS EOP C04 series.
- Investigation of the consistency between VLBI-only (IVS) CRF, TRF, and EOP series with the ITRF, ICRF, and C04 EOP series.
- Study of effects of geodetic datum realization on VLBI-derived CRF.
- Study of optimal use of the space-collocated techniques in improvement of the consistency between TRF, CRF, and EOP.

Members

Manuela Seitz (Germany), Chair
Susanne Glaser (Germany)
Richard Gross(USA)
Robert Heinkelmann (Germany)
Chris Jacobs (USA)
Sebastien Lambert (France)
Karine Le Bail (USA)
Zinovy Malkin (Russia)
David Mayer (Austria)
Dan MacMillan (USA)
Hana Krasna (Austria)

WG 1.4.2: Impact of Geophysical and Astronomical Modeling on Reference Frames and their Consistency

Chair: Dan MacMillan (USA)

Objectives

- Analysis and Solution Parameterization
  - More advanced gradient parameterization
  - Estimation of systematic temporal variation of source positions
  - Galactic aberration model
- External Models (Comparisons of models and effect on reference frames)
  - Loading models
  - Troposphere delay models (mapping functions or raytraced delays) based on numerical weather models
  - Effects arising from shifting from ITRF2008 to ITRF2014
- Internal Inconsistency
  - Declination zonal systematic CRF difference between 2009 and current solutions
  - Addition of Australian network data?
  - Troposphere estimation effect?
  - Other VLBI network dependent effects?

Members

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Robert Heinkelmann (Germany)
Tobias Nilsson (Germany)
Hana Krásná (Austria)
David Mayer (Austria)
Sebastien Lambert (France)
Manuela Seitz (Germany)
Zinovy Malkin (Russia)

WG 1.4.3: Improving VLBI-based CRF for Geodesy

Chair: Sébastien Lambert (France)

Objectives

The WG will address the way of improving the VLBI CRF and how these improvements can impact other geodetic products. The following items will be looked into:

- ICRS/ICRF definition in view of the latest developments in astrometry and space geodesy,
- Systematic errors in the current individual CRF realizations,
- Effects of changing the wavelengths due to, e.g., core-shift,
- Modeling and analysis options
- Interaction with futures Gaia-like CRF

Members

Sébasitien Lambert (France), Chair
François Mignard (France)
Maria Karbon (Germany)
Dan MacMillan (USA)
Zinovy Malkin (Russia)
Jacques Roland (France)
Manuela Seitz (Germany)
Stas Shabala (Australia)

Joint Working Groups of Commission 1

JWG 1.1: Site Survey and Co-Location
(joint with the IERS)

Chair: Sten Bergstrand (Sweden)
Vice-chair: John Dawson (Australia)

Terms of reference

The combination of space geodetic solutions is critically reliant on the availability of local tie vectors, which are the relative positions of the reference points of co-located space geodetic instruments determined by some survey technique. Tie vectors enter the combination of space geodetic solutions effectively as a fifth technique and are not only necessary for rigorous terrestrial reference frame realization but also serve to highlight the presence of technique- and/or site-specific biases.

With the ultimate objective of improving the accuracy of tie vectors as well as the consistency of space geodetic solutions, the Working Group (WG) will provide an authoritative source of surveying methodology advice, promote technical discussion, provide a forum for the evaluation of existing and new procedures and analysis strategies, and support the exchange of relevant information across GGOS and between the IAG technique services. Currently, dedicated points of contact (POC) have been established with IDS, IGS, ILRS and IVS. The WG will also support new survey activities with advice and advocate for re-survey where necessary.

Goals and objectives

Research:
- Revise existing local tie procedures
- Revise existing tie vector estimation processes
- Develop and define new methods

Coordination:
- Liaise with IERS combination centres
- Liaise with IAG technique services
- Direct research towards the investigation of technique specific systematic effects

Outreach:
- Remotely support local tie operations and tie vector estimation
- Spread the know-how
- Set guidelines

Members

Sten Bergstrand (Sweden), Chair
John Dawson (Australia), Vice-chair
Rüdiger Haas (Sweden)
Jim Long (USA)
Erricos Pavlis (USA)
Jerome Saunier (France)
Ralf Schmid, (Germany)

JWG 1.2: Modelling environmental loading effects for Reference Frame realizations
(joint with the IERS)

Chair: Tonie van Dam (Luxembourg)
Vice-chair: Anthony Mémin (France)

Terms of reference

The accuracy and precision of current space geodetic techniques are such that displacements due to non-tidal surface mass loading are measurable. Many scientific studies have already considered atmospheric loading corrections at the observation level. The modeling of other non-tidal loading effects has been also investigated by various authors. In parallel, a posteriori corrections have been shown to slightly decrease the variance factor of a Terrestrial Reference Frame (TRF) multi-technique combination but the improvement at some sites was also counterbalanced by degradation at others.

There still exist open questions regarding the application of loading corrections for the generation of operational geodetic products, either a priori or a posteriori: accuracy of the models in all frequency bands - sub-daily band is the most important for a priori corrections -, too few studies regarding available loading model agreement have been carried out, proper mass conservation of all contributions and degree 0 of each contribution, methods that should be use for interpolating the loading displacements, required model resolution, reference loads that are or should be used for geodetic products, contribution of ice melting at high latitude which is not modeled in current continental water loading models. The optimal usage of loading models is still to be defined in all possible applications.

The goal of this working group is to study the optimal usage of load models for TRF utilization.

Objectives

The principal objectives of the scientific work are to investigate optimal methods for applying load corrections for TRF development and usage, and to assemble specific recommendations for users.

Specific program activities

- Compare and assess differences between existing load models for a given effect.
- develop forward model of ice loading at high latitudes
- monitor geocenter motion variations to identify possible accelerations
- Maintain a bibliography on the available models and their evaluation.
- Assessment of the propagation of loading model errors into the site coordinates and the ITRF.
- Define whether models should be applied at the observation level or in the post-processing. In this case, define the best method (if any) to handle loading effects at the observation level (filtering, interpolation etc…).
- Tie results/findings to IERS conventions.
- Collect user opinions about what signals they need in station position time series (loading corrected or not).

Members

Tonie van Dam (Luxembourg), Chair
Anthony Mémin (France), Vice-chair
Zuheir Altamimi (France)
Johannes Böhm (Austria)
Jean-Paul Boy (France)
Xavier Collilieux (France)
Robert Dill (Germany)
Pascal Gegout (France)
Matt King (Australia)
Anthony Mémin (France)
Laurent Métivier (France)
Gerard Petit (France)
Jim Ray (USA)
Leonid Vitushkin (Russia)
Xiaoping Wu (China)

JWG 1.3: Troposphere Ties

Chair: Robert Heinkelmann (Germany)
Vice-chair: Jan Douša (Czech Republic)

Terms of Reference

Since many years, tropospheric parameters have been determined by space geodetic techniques, by other measurement techniques, such as water vapor radiometers, and, more recently, from model data, e.g. from numerical weather models. As tropospheric parameters we designate the hydrostatic and wet or total zenith delays and the horizontal gradients. Many comparative studies have revealed that besides statistical deviations the tropospheric parameters partly exhibit systematic differences. Such systematic differences might be caused by

- General differences, e.g. the different locations of the sensors, the different epochs of the observations and other e.g. meteorological ambient conditions;
- Effects due to hardware and hardware changes, e.g. change of the type of the GNSS antenna or effect of a radome at a station;
- The inter-technique systematics, for example due to different correlations among groups of parameters and / or due to the different sampling and geometry of observations;
- The application of different analysis models, such as the mapping functions, the different parameterizations used to represent the troposphere and the application of constraints during the adjustment, and, in addition;
- The post-processing methods of data handling for the comparison, e.g. the application of synchronization methods, such as interpolation, filtering, smoothing.

The terrestrial reference frame (TRF) is commonly realized by a combination of space geodetic techniques. For the combination of the techniques 'global ties', i.e. common global parameters, like the Earth Orientation Parameters (EOP), can be directly used, while 'local ties', i.e. common coordinates at co-location sites, have to consider the distances between the reference points of the various devices. The distances between the reference points are usually surveyed at site, but can also be indirectly assessed through the comparison of the positions determined by the various space geodetic techniques. The ground-based space geodetic techniques all observe targets in or above the atmosphere and consequently common atmospheric parameters might be used to link the techniques as well. The systematics between tropospheric parameters obtained by different sensors have to be considered to reasonably perform this combination approach. With 'tropospheric ties' we designate the systematics that enable a combination of tropospheric parameters if they are appropriately considered.

Objectives

The main objective of the working group is (i) to assess the systematics between tropospheric parameters obtained at different locations, times, and by different measurement techniques: tropospheric ties. The other focus is (ii) to test the application of tropospheric ties for the combination of the space geodetic techniques. Accordingly, the group will work on

- Extensive comparisons of tropospheric parameters;
- Theoretical modeling based on hydrostatic equilibrium and comparable assumptions;
- Numerical modelling involving numerical weather models; and
- Testing the combination with the application of the tropospheric ties.

Members

Robert Heinkelmann (Germany), Chair
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