Symposium 1: Reference Frames

Organizer: Christopher Kotsakis (Greece) President Commission 1

Co-organizers: Jean-Paul Boy (France) Vice-President Commission 1
Urs Hugentobler (Germany) Chair Sub-Commission 1.1
Xavier Collilieux (France) Chair Sub-Commission 1.2
Carine Bruyninx (Belgium) Chair Sub-Commission 1.3
Zinovy Malkin (Russia) Chair Sub-Commission 1.4

Abstract

Reference frames offer the foundation for quantifying the geometry, gravity field and rotation of the deformable Earth, and they are the principal tool for the consistent assimilation of their temporal variations in global change studies. Furthermore, reference frames have primary importance in satellite navigation and precise orbit determination, and they provide the backbone for high-accuracy positioning and geospatial information management. Essentially all aspects of modern geodesy depend on the realization and proper maintenance of reference frames that are delivered by space geodetic techniques using high-level modeling schemes to reduce observational errors and to meet stringent accuracy requirements for scientific users.

The central scope of the Symposium is to address present-day achievements on the theoretical aspects and the practical realization of reference frames by individual space geodetic techniques and their combinations. The emphasis is given on global and regional terrestrial frames, celestial reference frames, and the co-location of space geodetic techniques on ground and in space. Reference frame requirements, usage and applications for an improved understanding of Earth dynamics will be also addressed in the Symposium, including topics such as tectonic plate motion, glacial isostatic adjustment, environmental loading effects, geocentre motion, seismic deformation, local subsidence and other crustal displacements. Besides focusing on the current state of geodetic frame theory and its implementation, the Symposium aims at looking beyond current practices by underlying limiting factors and discussing novel approaches for future improvements in frame realizations for Earth science applications.

Symposium 1, Session 1
International Terrestrial Reference Frame: strengths, weaknesses and strategies for future improvements

Convener: Xavier Collilieux (Institut National de l' information Geographique et Forestiere, France, xavier.collilieux@ensg.eu)
Co-Convener: Anthony Mémin (Université Nice Sophia Antipolis, France, memin@geoazur.unice.fr)
Ryan Hippenstiel (National Geodetic Survey NOAA, USA, ryan.hippenstiel@noaa.gov)

Abstract
The Terrestrial Reference Frame is fundamental for monitoring Earth rotation in space and for all geoscience applications that require absolute positioning and precise orbit determination of artificial satellites. The International Terrestrial Reference Frame (ITRF) series are determined using geodetic data from Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), Global Navigation Satellite Systems (GNSS), Satellite Laser Ranging (SLR) and Very Long Baseline Interferometry (VLBI). Their overall accuracy depends on data modeling strategies, on the precision of the relative position of geodetic instruments at co-location sites (local tie survey) and on the combination strategy in the final data adjustment.

A new release of the International Terrestrial Reference Frame, namely ITRF2020, is currently under preparation. The objective of this session is to discuss any advancement that could lead to an improvement of the next Terrestrial Reference Frames in terms of accuracy of the frame parameters and station coordinates. The following topics are of specific importance:

- Recent space geodetic data modeling updates and mitigation of technique systematic errors.
- New local tie determination and challenges.
- Impact of nonlinear station motions (loading effects, post-seismic deformation, etc.) and their modeling on the terrestrial reference frame.
- Combination strategies for the ITRF determination.

Keywords: International Terrestrial Reference Frame (ITRF), DORIS, GNSS, SLR, VLBI, multi-technique combination, frame estimation, local ties, secular/non-secular station motions, GIA, loading effects.

Symposium 1, Session 2
Advancements and open problems in global reference frame theory and methodology

Convener: Christopher Kotsakis (Aristotle University of Thessaloniki, Greece, kotsaki@topo.auth.gr)
Co-Convener: Mathis Blossfeld (TUM, Germany)

Abstract
The goal of this session is to provide a forum to discuss the current state of reference systems theory and its implementation aspects for the realization of global terrestrial reference frames (TRFs) on the deforming Earth. It aims also to look beyond current practices by addressing open problems, data modeling issues and methodological advancements that are crucial for augmenting both the long-term stability and the short-term predictability of station positions in global TRFs. Some themes of particular interest are: the handling of non-secular station motions in frame estimation and the choices for their regularized parameterization, the realization of frame origin in relation to diverse needs of scientific users, the treatment of geocenter motion in multi-year frame solutions, the treatment of scale drift and its influence on the geophysical interpretability of predicted station displacements, and the significance of network effects along with their mitigation strategies. The session solicits contributions covering the complete range of topics in geodetic frame theory and estimation, including

- Conceptual definitions and adequacy of adopted conventions.
- Improved methods to realize global TRFs by individual space techniques and combination methods.
- Incorporation of new data analysis models and updated processing strategies.
- Better TRF utilization and novel reference frame representations to serve Earth science applications.
- Accuracy quantification of global TRF solutions.

Keywords: Global reference frames, station kinematic models, non-secular frames, geocenter motion, non-tidal loading, single-technique/multi-technique solutions, scale drift, Earth science applications.
.

Symposium 1, Session 3
Terrestrial and space geodetic ties for multi-technique combinations

Convener: Urs Hugentobler (Technical University of Munich, Germany, urs.hugentobler@tum.de)
Co-Convener: Krzysztof Sośnica (Wroclaw University of Environmental and Life Sciences, Poland, krzysztof.sosnica@igig.up.wroc.pl)

Abstract
Consistent combination of space geodetic techniques is a necessity for a full exploitation of the relative strength of the techniques for the generation of accurate and long-term stable geodetic products. Essential for this task are precise ties between the different techniques, co-located on ground and in space. This session aims at a review of the state-of-the art and outlook to future prospects as well as assessment of the impact on geodetic products of precision sight surveys, monitoring of temporal variations of tie vectors, identification of technique-specific biases, space geodetic combination methodologies, but also of using additional and novel tie information such as intra- and inter-technique tropospheric ties or ties realized through common clock parameters at geodetic observatories, as well as exploitation of already existing space ties such as SLR observations of GNSS satellites, experiments of observing GNSS satellites with VLBI, and simulations of the impact and benefit of future space co-location missions.

The following topics are of specific importance:
- Identification of technique-specific biases.
- Temporal variations of tie vectors at co-located stations.
- Intra- and inter-technique ties based on tropospheric parameters and common clock parameters.
- Space-based ties using GNSS-satellite tracking via SLR or VLBI measurements.

Keywords: Terrestrial/space geodetic ties, terrestrial reference frames, multi-technique combination, local tie vectors, co-located techniques, tropospheric parameters, SLR-to-GPS tracking.

Symposium 1, Session 4
Regional reference frames and networks

Convener: Carine Bruyninx (Royal Observatory of Belgium, C.Bruyninx@oma.be)
Co-Convener: Richard Stanaway (School of Civil and Environmental Engineering, UNSW, Australia, richard.stanaway@quickclose.com.au)

Abstract

The main scope of this session is to provide a forum for addressing activities, results and key issues of common interest to the regional sub-commissions of the IAG Sub-commission 1.3 “Regional Reference Frames”. The session solicits contributions regarding the development and implementation of regional reference frames, and their connection to the International Terrestrial Reference Frame in compliance with the IGS framework. Of special interest to the session are papers focusing on ground-based GNSS networks for the long-term maintenance of regional frames and the monitoring of residual tectonic station motions. In addition, papers are also sought with regard to scientific and practical applications in positioning, mapping, navigation, and environmental/climate modeling that rely on regional reference frames and their supplementary products offered by operational network services and data analysis centers. The temporal instability in regional frames due to unmodeled geodynamical effects, in conjunction with the need of time-dependent transformation models for regions affected by glacial isostatic adjustment and seismic crustal deformations, is an important theme of high interest for this session. We particularly welcome contributions exposing theoretical and practical issues for the time evolution of regional reference frames, and the seamless implementation of time-dependent deformation models and transformation methodologies to achieve the highest possible accuracy and consistency in regional frame realizations over deforming zones.

This session solicits contributions focusing on the following aspects:

- Regional reference frames and their applications.
- Maintenance, operational aspects, data management and solution products in continuously operated GNSS networks.
- Methodologies and accuracy specifications for regional frame densifications (especially for active tectonic regions).
- Effects of crustal motion and other episodic displacements in regional frames, and the importance of local deformation models for aligning to global frames (ITRF).
- Implementation of time-dependent transformation models in GIS platforms.

Keywords: Regional reference frames, GNSS permanent networks, frame densification, crustal deformation models, plate tectonic motion, GIA, frame alignment, time-dependent transformation models.

Symposium 1, Session 5
Comparison and combination of space geodesy techniques for improving consistency between TRF, CRF and EOPs

Convener: Robert Heinkelmann (Helmholtz Centre Potsdam GFZ, Germany, rob@gfz-potsdam.de)
Co-Conveners: Zinovy Malkin (Pulkovo Observatory, Russia, zmalkin@zmalkin.com)
Manuela Seitz (Technical University of Munich, Germany, manuela.seitz@tum.de)

Abstract

The international terrestrial and celestial reference frames, ITRF and ICRF, respectively, as well as the link between them expressed by the Earth Orientation Parameters (EOP) are key products of geodesy and astrometry. Many scientific and practical applications rely on the consistency of ITRF, ICRF, and EOP, and the requirements to all the components of this triad with respect to accuracy, precision and consistency grow steadily. Today, ITRF and ICRF are computed separately, but are linked by cross-alignments or by fixing parameters. While the ITRF and consistently estimated EOP series are derived from a combination of the four space geodetic techniques VLBI, SLR, GNSS and DORIS, the ICRF and the related EOP series are derived from VLBI observations only. To reach a high consistency between the products, the homogeneity of geophysical and astronomical models, of geodetic datum, and of parameterization is necessary. The topics discussed in this session will include the comparison and combination of EOP and TRF solutions derived by different techniques, as well as comparison of VLBI-only and multi-technique CRF realizations including assessing and understanding the systematic differences between them, and their impact on EOP estimates. A further important discussion topic will be issues currently preventing the realization of the terrestrial and celestial reference systems at the mm/μas level of accuracy, such as deficiencies of the station network including station instabilities, technological (precision) limitations of existing techniques, incompleteness of the theory and models, not fully understood and agreed-upon details of the processing strategy, and others. The session solicits contributions to all these topics.

This session solicits contributions focusing on the following aspects:

- Comparison and combination of EOP solutions by different techniques.
- Comparison and combination of TRF solutions derived by different techniques.
- Comparison of VLBI-based and combined multi-technique CRF realizations.
- Unification of astronomical and geophysical modeling.

Keywords: Terrestrial Reference Frame (TRF), Celestial Reference Frame (CRF), Earth Orientation Parameters (EOPs), space geodetic techniques, VLBI, multi-technique CRF realization.

Symposium 1, Joint Session: Commissions 1 and 2, GGOS, ICCT, QuGe Project
Vertical Reference Systems: methodologies, realization, and new technologies

Convener: George S. Vergos (Aristotle University of Thessaloniki, Greece, vergos@topo.auth.gr)
Co-Convener: Christopher Kotsakis (Aristotle University of Thessaloniki, Greece, kotsaki@topo.auth.gr)
Co-Convener: Jianliang Huang (Natural Resources Canada (NRC), Canada, jianliang.huang@canada.ca)
Co-convener: Laura Sánchez (Technical Deutsches Geodätisches Forschungsinstitut (DGFI-TUM), Arcisstr. 21, 80333 Munich, Germany; lm.sanchez@tum.de)
Co-Convener: Jakob Flury (Institut für Erdmessung; Leibniz Universität Hannover, Schneiderberg 50, 30167, Hannover, Germany; flury@ife.uni-hannover.de)

Abstract

This session focuses on the unification of the existing height systems and vertical datums around the world, which can be achieved through the realization of an international vertical reference system that supports geometrical (ellipsoidal) and physical (normal, orthometric) heights with centimeter precision in a global frame. The latter, enables the unification of all existing physical height systems, and provides high-accuracy and long-term stability of the vertical coordinates. To guarantee a precise combination of physical and geometric parameters and to support the vertical datum unification worldwide, the IHRF network should be collocated with fundamental geodetic observatories, geometrical reference stations, reference tide gauges, local levelling networks, and gravity reference stations. In fact, the predictability of physical height changes depends drastically on the consistent integration between IHRS and ITRF, and the standardization of their respective modeling for time variable effects related to surface loading, mass-transfer processes, geocenter motion, frame scale drift, etc.. A lot of important issues of theoretical and practical significance arise in this context, which have not been yet resolved to meet the accuracy requirements of GGOS (and its scientific users) for the most stringent applications such as long-term sea level change and vertical land motion. Moreover, novel approaches for potential and height determination based on relativistic geodesy towards height system realization are becoming tangible hence offering new perspectives in the realization of vertical reference systems. Finally, definitions and realizations of local vertical datums relying on purely oceanographic, geodetic and hybrid methods, pose the problem of their combination and unification to the IHRS. Within this framework, contributions related to the following topics are invited:

- Refinement of standards and conventions for the definition and realization of vertical reference systems, in particular those standards needed for the realization of the IHRS.
- Strategies for the establishment of precise vertical reference frames, in particular the establishment of the IHRF.
- Precise determination and modelling of geopotential values for the realization of IHRF network.
- Precise determination and modelling of the time-dependent changes of the vertical coordinates and the datum itself.
- Theory and methodology for height system unification, in particular the connection/transformation of existing height systems to the IHRS/IHRF.
- Recent results on vertical datum unification, including the connection of vertical datums over oceans.
- Strategies for collocation of vertical reference stations (i.e., IHRF stations) with existing reference frames (GGOS core stations, ITRF, gravity stations, existing levelling networks, etc.).
- IHRS/ITRF synergy and related open problems.
- Geometric frame effects on physical height systems.
- Development of a registry (metadata) containing the existing height systems and their connections to the IHRS/IHRF.
- Relativistic geodesy and clocks for potential determination. Impact on height system determination and realization.
- Improvements in clock performance. Novel approaches for integration with existing height determination methodologies, error treatment and assimilation.

Keywords: International Height Reference System (IHRS), International Height Reference Frame (IHRF), Vertical Datum, global unified vertical reference system, geopotential height datum, permanent tide, tide systems, time-dependent IHRS, IHRF/ITRF synergy, relativistic geodesy, precise clocks.