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Review

Global geodetic observatories

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Abstract

Global geodetic observatories (GGO) play an increasingly important role both for scientific and societal applications, in particular for the maintenance and evolution of the reference frame and those applications that rely on the reference frame for their viability. The International Association of Geodesy (IAG), through the Global Geodetic Observing System (GGOS), is fully involved in coordinating the development of these systems and ensuring their quality, perenniality and accessibility. This paper reviews the current role, basic concepts, and some of the critical issues associated with the GGOs, and advocates for their expansion to enhance co-location with other observing techniques (gravity, meteorology, etc). The historical perspective starts with the MERIT campaign, followed by the creation of international services (IERS, IGS, ILRS, IVS, IDS, etc). It provides a basic definition of observing systems and observatories and the build up of the international networks and the role of co-locations in geodesy and geosciences and multi-technique processing and data products. This paper gives special attention to the critical topic of local surveys and tie vectors among co-located systems in sites; the agreement of space geodetic solutions and the tie vectors now place one of the most significant limitations on the quality of integrated data products, most notably the ITRF. This topic focuses on survey techniques, extrapolation to instrument reference points, computation techniques, systematic biases, and alignment of the individual technique reference frames into ITRF. The paper also discusses the design, layout and implementation of network infrastructure, including the role of GGOS and the benefit that would be achieved with better standardization and international governance.

Keywords: Global geodetic observatories; GGOS; Space geodesy; Space geodetic techniques; Co-locations; Tie vectors

Contents

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1. Introduction

Global geodetic observatories (GGOs) host ground-based infrastructure of geodetic observing systems to monitor properties of the Earth System, including its various components: solid Earth, ocean, atmosphere, cryosphere, and biosphere. These observing systems include some combination of Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), Global Navigation Satellites Systems (GNSS), and Doppler Orbitography and Radiopositioning Integrated by Satellites (DORIS), as well as other types of instruments such as gravimetric sensors, geophysical or environmental sensors, etc. Data products derived from networks of GGOs provide data to help us to understand the nature of global phenomena, how they are linked, how they change in time and how they affect our lives. Measurements allow us to model the effects and forecast their evolution, but even more important, they form the scientific basis on which long-term actions can be planned and reasonable policies can be adopted to allow society to better contend with current trends and future conditions.

The major role of GGOs is to provide connections between various global observing systems, through ground co-locations of their instruments. Each technique measures something different, but in combination, these provide very rich sources of data to promote geophysical understanding. Local tie vectors and proper instrument modeling provide the means to inter-compare and combine the results from the separate co-located systems. This allows us to characterize the systematic differences between techniques and to construct integrated data products that take advantage of the individual technique strengths while mitigating the weaknesses. The quality of the GGO data products depends on the strength of the network including the number of sites, geographical distribution, and the quality and quantity of the individual systems measurements. The GGO may also provide the ideal infrastructure to host new instruments.

The International Association of Geodesy (IAG) is presently the reference international organization dealing with GGOs. The IAG's Global Geodetic Observing System (GGOS) and its Sub-Commission 1.2 are focused on the development and improvement of the Global Reference Frames as the basis for accurately connecting metric measurement over space (thousands of kilometers), time (decades) and evolving technology (see Beutler and Rummel, 2012; Plag and Pearlman, 2009; Rummel et al., 2005). Agencies in many countries are developing national reference frames for internal benefit and as their contribution to the international activity. See for instance the recent report established by the US National Research Council (NRC, 2010). This bottom-up and best effort mechanism leaves geographic and technological gaps as well as unnecessary duplications. With proper international governance and funding these gaps and duplications could be minimized and the importance of the GGO infrastructure for observations of the Earth, as discussed in the Global Earth Observation (GEO) initiative (see: https://www.earthobservations.org/documents/work%20plan/geo_wp1215_rev3_140123.pdf) could be better publicized.

The IAG established the Global Geodetic Observing System (GGOS) in 2003 to integrate the three fundamental areas of geodesy (Earth's shape, gravity field, and rotation), to monitor geodetic parameters and their temporal variations in a global reference frame with an accuracy of 10^{-9} or better (Plag and Pearlman, 2009). GGOS is intended to provide data products and services with sufficient geodetic accuracy, consistency, and continuity to address important geophysical questions and to help us make intelligent decisions on societal needs. This includes the decisions that we make regarding our national and international resources, our populations, and our environment. GGOS is constituted mainly from the Services, ILRS, IVS, IGS, IDS (Dow et al., 2009; Pearlman et al., 2009; Schuh and Behrend, 2012; Willis et al., 2010) and the International Earth Rotation and Reference Systems Service (IERS) and, although it has a wide spectrum of interest, the main focus at the moment is on the improvement of the International Terrestrial Reference Frame (ITRF).

The US National Research Council Study (NRC, 2010) found that the most stringent requirement for the ITRF