

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_o 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_o value has been accomplished, and a suitable W_o 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)

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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 $2 \text{ m}^2 \text{ s}^{-2}$ 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: