

## Focus Area 1: Unified Height System

Chair: L. Sánchez (Germany)

The objective of Focus Area 1 is the unification of the existing vertical reference systems around the world. This should be achieved through the definition and realization of a global vertical reference system that

- supports geometrical (ellipsoidal) and physical (normal, orthometric, geoidal) heights world-wide with centimetre precision in a global frame;
- enables 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  $W_0$ ); and
- provides high-accuracy and long-term stability of the vertical coordinates.

A first step towards the establishment of a worldwide unified (standardized) height system was the release of an IAG resolution for the definition and realization of an *International Height Reference System* (IHRs) that was issued during the 2015 IUGG General Assembly. This resolution outlines the conventions for the definition of the IHRs in terms of potential parameters: the vertical coordinates are geopotential numbers referring to an equipotential surface of the Earth's gravity field realized by the conventional value  $W_0 = 62\,636\,853.4 \text{ m}^2/\text{s}^2$ . At present, the main challenge is the realization of the IHRs, i.e., the establishment of the *International Height Reference Frame* (IHRF). It is expected that the IHRF follows the same structure as the ITRF: a global network with regional and national densifications, with known geopotential numbers referring to the global IHRs. To guarantee a precise combination of physical and geometric parameters and to support the vertical datum unification worldwide, this reference network should be collocated with fundamental geodetic observatories, geometrical reference stations, reference tide gauges, local levelling networks, and gravity reference stations. For this purpose, it will use contributions from all IAG Commissions, and the available databases, standards and infrastructure of the IAG/GGOS Services.

### Planned activities

- Refinement of standards and conventions for the definition and realization of the IHRs, including unification of standards and conventions that are used by the *geometric* and *gravity* Services of the IAG.
- Develop of GGOS products for the realization of the IHRs.
- Recommendation for a global vertical reference frame; i.e. the IHRF.
- Guidelines/procedures for height system unification.
- Development of a registry (metadata) containing the existing local/regional height systems and their connections to the global one.
- Strategies for the maintenance and use in practice of the IHRs.
- Determination and modelling of the temporal changes of the IHRF.
- Update the IHRs definition and realization as needed, based on future improvements in geodetic theory and observations.
- Servicing the vertical datum needs of other geosciences such as, e.g., hydrography and oceanography.

Efforts are currently underway to establish working groups and processing centres that will focus on one or more of the action items above. One such group is the already established JWG 0.1.1, whose objectives are outlined below.

#### Joint Working Group of Focus Area 1

##### **JWG 0.0.1: Strategy for the Realization of the International Height Reference System (IHR)** (joint with Commissions 1 and 2, the Inter-commission Committee on Theory, and the International Gravity Field Service)

Chair: L. Sánchez (Germany)

The IAG Resolution No. 1 released during the IUGG 2015 General Assembly outlines five conventions for the definition of the International Height Reference System (IHR). The definition is given in terms of potential parameters: the vertical coordinates are geopotential numbers ( $-\Delta W_P = C_P = W_0 - W_P$ ) referring to an equipotential surface of the Earth's gravity field realized by the conventional value  $W_0 = 62\,636\,853.4 \text{ m}^2\text{s}^{-2}$ . The spatial reference of the position  $P$  for the potential  $W_P = W(\mathbf{X})$  is given by coordinates  $\mathbf{X}$  of the International Terrestrial Reference Frame (ITRF). This Resolution also states that parameters, observations, and data shall be related to the mean tidal system/mean crust.

At present, the main challenge is the realization of the IHR; i.e., the establishment of the International Height Reference Frame (IHRF): a global network with regional and national densifications, whose geopotential numbers referring to the global IHR are known. According to the GGOS objectives, the target accuracy of these *global* geopotential numbers is  $1 \times 10^{-2} \text{ m}^2\text{s}^{-2}$ . In practice, the precise realization of the IHR is limited by different aspects; for instance, there are no unified standards for the determination of the potential values  $W_P$ , the gravity field modelling and the estimation of the position vectors  $\mathbf{X}$  follow different conventions, the geodetic infrastructure is not homogeneously distributed globally, etc. This may restrict the expected accuracy of  $1 \times 10^{-2} \text{ m}^2\text{s}^{-2}$  to some orders lower (from  $10 \times 10^{-2} \text{ m}^2\text{s}^{-2}$  to  $100 \times 10^{-2} \text{ m}^2\text{s}^{-2}$ ). Consequently, the next step is to outline the minimum set of fundamentals needed for a reliable and sustainable realization of the IHR.

According to this, the objectives of the JWG 0.0.1 are:

- To define the standards and conventions required to establish an IHRF consistent with the IHR definition. A main issue is the high-precise modelling of the time-dependent changes of the vertical coordinate (which also reflect time variations of  $\mathbf{X}$  and  $W$ ).
- To formulate minimum requirements for the IHRF reference stations.
- To develop a strategy for collocation of IHRF reference stations with existing geometrical reference stations at different densification levels.
- To identify the geodetic products associated to the IHRF and to describe the elements to be considered in the corresponding metadata.
- To review the processing strategies for the determination of the potential values  $W_P$  and to recommend an appropriate computation procedure based on the accuracy level offered by those strategies.
- To review different approaches for the vertical datum unification and to provide guidance for the integration of the existing local height systems into the global

IHRS/IHRF.

- To make a proposal about the organizational and operational infrastructure required to maintain the IHRF and to ensure its sustainability.

The main result of this JWG should be a document similar to the IERS conventions; i.e., a sequence of chapters describing the different components to be consider for the precise and sustainable realization of the IHRS and its practical utilization.

The activities of this JWG are based on the results presented by previous work, in particular those of the IAG Inter-Commission Project 1.2: Vertical Reference Frames (conventions for the definition of World Height System, 2003 – 2011); GGOS Focus Area 1 (former Theme 1): Unified Height System (action Items for the unification height reference systems, since 2011); the ESA project “GOCE+ Height System Unification with GOCE” (2011-2014); the GGOS-BPS (inventory of standards and conventions used for the generation of IAG/GGOS products, since 2011); and the Joint Working Group on Vertical Datum Standardisation (2011-2015).

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