Operational Infrastructure to Ensure the Long-Term Sustainability of the International Height Reference System and Frame (IHRS/IHRF)

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Abstract

The International Association of Geodesy (IAG) introduced the International Height Reference System (IHRS) in 2015 as an international standard for the accurate determination of physical heights worldwide. Primary vertical coordinates are geopotential numbers referenced to a conventional W_0 value. The realisation of the IHRS is the International Height Reference Frame (IHRF), which corresponds to a global network of reference stations with precise reference coordinates specified in the IHRS. The spatial position of the stations, at which the geopotential numbers are calculated, is defined by their respective coordinates (X, Y, Z) in the International Terrestrial Reference Frame (ITRF). The realisation of the IHRS is thus based on the combination of a geometric component, given by the positions of the stations in the ITRF, and a physical component, given by the determination of the potential values W at these positions. Through a strong international collaboration, framed by the IAG, it has been possible in recent years to pave the scientific foundations of the IHRS, to compute a first solution of the IHRF, and to identify the key requirements for a long-term sustainability of the IHRF. Much progress has been made and continuity is needed to ensure the maintenance and availability of the IHRF in the future. Following IAG practice, the development of theory and methods for the continuous improvement of the IHRS/IHRF should be promoted by the IAG Commissions and the Inter-Commission Committee on Theory (ICCT), while the operational performance should be ensured by the IAG Services. In this paper, we highlight the organisational challenges in maintaining the IHRS/IHRF, discuss how the existing gravity field related IAG Services could contribute to the IHRS/IHRF, and identify the elements needed to establish an operational infrastructure for the IHRS/IHRF that addresses the organisational challenges. Our proposal is to establish a central coordinating body under the responsibility of the International Gravity Field Service (IGFS), composed of individual modules taking care of the main components of the IHRS/IHRF. The central management body is the IHRF Coordination Centre and its modules are the IHRF Reference Network Coordination, the IHRF Conventions' Coordination, the IHRF Associate Analysis Centres, and the IHRF Combination Coordination. The IGFS presented this proposal to the IAG Executive

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International Association of Geodesy Symposia,
https://doi.org/10.1007/1345_2024_250,

Committee at its meeting on 10 December 2023 and it was unanimously approved. Thus, a new component of the IGFS dedicated to the IHRF has been created and will ensure the long-term availability and reliability of the IHRF.

Keywords

IHRF Coordination Centre · International Gravity Field Service (IGFS) · International Height Reference Frame (IHRF) · International Height Reference System (IHRS)

1 Introduction

The International Association of Geodesy (IAG) introduced the International Height Reference System (IHRS) in 2015 as the international standard for the precise determination of physical heights worldwide (see IAG Resolution 1 (2015) in Drewes et al. 2016). The IHRS is a geopotential-based reference system co-rotating with the Earth. The primary coordinates are potential differences (i.e., geopotential numbers C_P) between the potential W_P of the Earth's gravity field at a point P, and the geoidal potential value W_0 (Ihde et al. 2017; Sánchez et al. 2021)

$$C_P = W_0 - W_P. \tag{1}$$

The realisation of the IHRS is the International Height Reference Frame (IHRF), which is composed of a global network of reference stations with precise reference coordinates (X, Y, Z, C) specified in the IHRS as well as in the International Terrestrial Reference Frame (ITRF, e.g. Altamimi et al. 2023). Thus, the realisation of the IHRS is based on the combination of a geometric component, given by the station positions in the ITRF, and a physical component, given by the determination of the potential values W at these positions.

The definition and initial realisation of the IHRS were implemented under the coordination of the Focus Area Unified Height System (FA-UHS) of the IAG's Global Geodetic Observing System (GGOS) (Plag and Pearlman 2009; Sánchez and Barzaghi 2024). The establishment of a global unified height system was one of the earliest priorities of GGOS, as this topic had been discussed for many decades and required the concurrence of several IAG components, namely, Commission 1 (Reference Frames), Commission 2 (Gravity Field), the Inter-Commission Committee on Theory (ICCT), the International Gravity Field Service (IGFS), and the International Earth's Rotation and Reference Systems Service (IERS). Since 2011, the GGOS FA-UHS has convened representatives from these IAG entities to implement a world height system and these joint efforts have enabled the definition of the IHRS, an initial solution of the IHRF, and the compilation of a cookbook for the IHRF. This cookbook comprises (Sánchez et al. 2021):

– A catalogue of basic standards and conventions including numerical constants, reference ellipsoid, zero degree and mass centre convention, handling of permanent tide effects, etc.,
– guidelines for the determination and evaluation of IHRF coordinates depending on the data availability and quality, and
– strategies for improving the input data required for the determination of IHRF coordinates and for the densification of the global IHRF at the regional and national levels.

With these foundations in place, the next step is to ensure the long-term maintenance and service of the IHRF. Following IAG practice, the operational activities needed for the IHRF should be undertaken by an IAG Service, in this case the IGFS, while future developments in theory and data analysis should be supported by the IAG Commissions and other components, in this case, Commissions 1 and 2, the ICCT and the IAG Project Novel Sensors and Quantum Technology for Geodesy (QuGe). The latter is of particular importance in view of the near future possibility of determining potential differences with precise optical clocks (see e.g., Müller et al. 2018; Wu et al. 2019; Wu and Müller 2020) and quantum satellite gradiometry (see e.g., Migliaccio et al. 2023; Mu et al. 2023).

While the scientific foundations and challenges in the determination of the IHRF are widely discussed in Ihde et al. (2017), Sánchez et al. (2016, 2021), Sánchez and Sideris (2017), Wang et al. (2021), this contribution summarises our findings on the operational and organisational elements required to ensure adequate long-term availability of the IHRS/IHRF. In Sect. 2, we describe the constituent elements of the IHRS/IHRF. In Sect. 3, we highlight the challenges in sustaining the IHRS/IHRF. In Sect. 4, we summarise how the existing gravity field-related IAG Services could contribute to the IHRS/IHRF and vice versa. In Sect. 5, we identify the missing elements and interfaces that need to be established within the IGFS for the maintenance of the IHRS/IHRF.

2 Constituent Elements of the IHRS/IHRF

As with any reference system, the definition of the IHRS outlines the fundamental conventions of the system: the type of coordinates, what they refer to, the units to express the coordinates, the permanent tide concept in which the coordinates must be expressed, etc. The materialisation of the definition is given by a reference frame that realises the system physically and mathematically. The physical realisation establishes a set of stations or continuously operating instruments that allow tangible access to the system. The mathematical realisation determines the reference coordinates at the reference stations following the definition of the system precisely. The latter is achieved through the use of specific constants, standards and procedures that ensure the exact observance of the conventions given in the definition. For example, in the case of the IHRS, two defining conventions state that the coordinates (geopotential numbers) should be given with respect to a specific W_0 reference value (Sánchez et al. 2016) and in the mean permanent tide concept (Mäkinen 2021). Thus, the IHRF coordinates (mathematical realisation) cannot be given with respect to another W_0 value or in another permanent tide concept, because this would not realise the IHRS defined. Continuing with this example, since the potential of the Earth's gravity field cannot be calculated in the mean permanent tide concept (e.g., Sánchez et al. 2021; Wang et al. 2021), common standards are required to remove the direct (and indirect) effects of the permanent tide before the potential values are calculated and then to restore these effects to make the IHRF coordinates consistent with the definition. Definition, realisation, and standards are the first three constituents of the IHRS/IHRF. They represent the state-of-the-art at the time when they were introduced. When theoretical or technological developments in the gravity potential analysis are implemented, the definition of the system, the mathematical realisation, and the standards (procedures) have to be updated accordingly, with rigorous assessment of the changes and implications that these updates bring to IHRS and its realisation. When stations belonging to the realisation are decommissioned or new stations are integrated into the IHRF, the physical realisation has to be updated accordingly. These updates should be timely to ensure that the IHRS and IHRF reflect and are able to support the latest developments in geodesy and that the IHRF is delivered to users in a timely and reliable manner. Thus, the fourth constituent of the IHRS/IHRF is their maintenance, evolution, and long-term availability. Finally, the fifth constituent, as we understand it, is the people who do the work, also the organisational structure that runs the stations, archives and analyses the data, maintains standards and conventions, validates and publishes the results. Figure 1 summarises the IHRS/IHRF constituents and how they interact.

3 Organisational Challenges in the Maintenance of IHRS/IHRF

The determination of the ITRF coordinates follows the IERS Conventions (Petit and Luzum 2010) and is supported by a fully operational infrastructure (reference stations, data centres, analysis centres, combination centres, product centres, etc.) acting under the responsibility of the IAG geometric services and the IERS. Based on more than 30 years of experience (the first ITRF solution was released in 1989: ITRF0; Boucher and Altamimi 1989), the maintenance and routine calculation of the ITRF, including the quality assessment of station positions and velocities, is well established in practice. Such an integrated infrastructure for physical heights is required for the IHRF.

The determination of the IHRF geopotential values C relies on the calculation of the gravity potential W, which is only possible by means of gravity field modelling. As W is non-linear and non-harmonic, a series of approximations are required:

– As W can be determined up to a constant only, the gravitational potential V is assumed to vanish at ∞
– To deal with the non-linearity and non-harmonicity of W, it is linearised by subtracting the gravity potential U generated by a reference level ellipsoid, currently the GRS80 (Geodetic Reference System 1980; Moritz 2000), obtaining the disturbing potential T:

$$T = W - U. \tag{2}$$

Since U is analytically known (Hofmann-Wellenhof and Moritz 2005), if T is known, the potential W and thus, the IHRF geopotential numbers (Eq. 1) can be easily derived. T must be known at the surface of the Earth (at the point P). When calculating the geoid (N), T is determined at the geoid surface. As a result, for the IHRF, T must be continued upwards to the surface of the Earth. If the height anomaly (ζ) is estimated, T can be directly used in Eq. (2) without further modifications (see e.g., Ihde et al. 2017; Sánchez et al. 2021).
– The solution of T demands a *mass-free* external space. Thus, the gravitational effects due to the Sun, Moon, topography, and other disturbing masses must be removed before the calculations and then restored to the final results to obtain the IHRF coordinates in the mean permanent tide concept.
– The determination of T at any point requires the integration of all the Earth masses. Therefore, the combination of

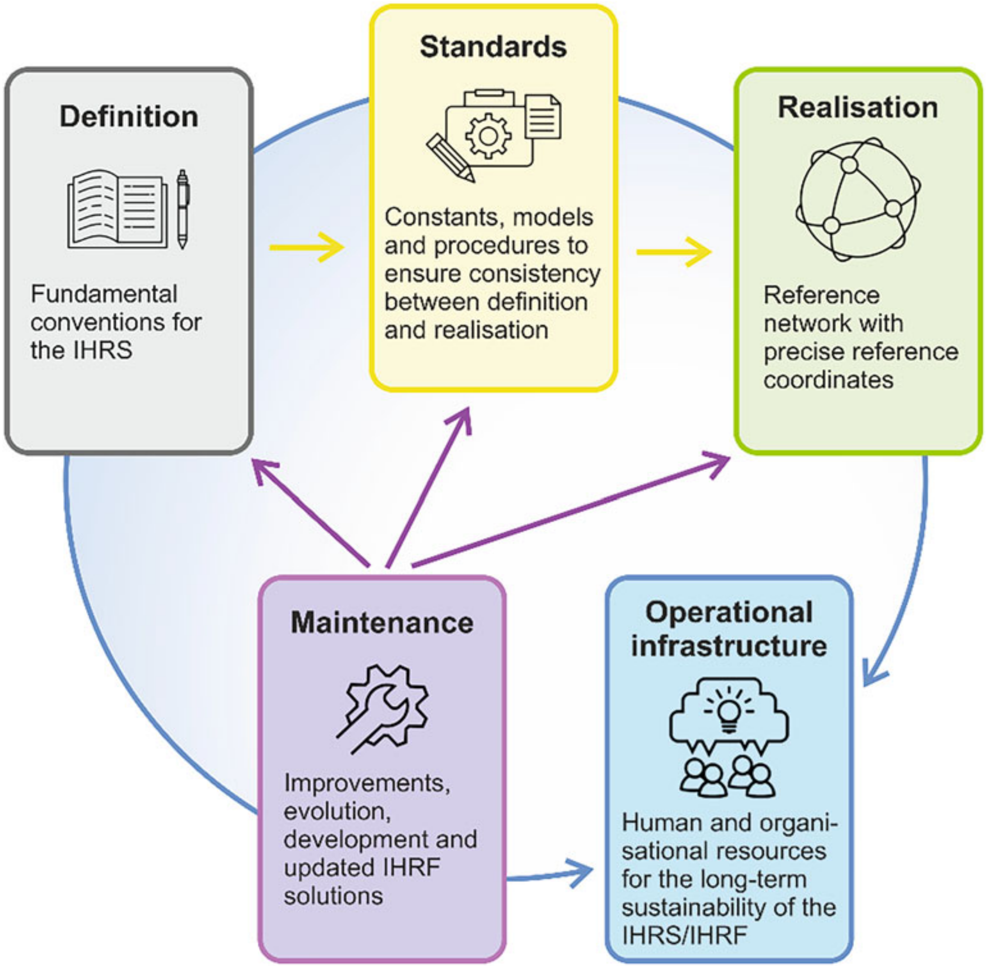

Fig. 1 Constituent elements of IHRS/IHRF

global gravity models with in situ surface (terrestrial, airborne or marine) gravity data is needed. This combination has to be adapted to the available surface gravity data coverage and quality, resulting in integral formulas with different analytical approximations.

– The mathematical evaluation of *T* can also be performed with different formulations (e.g., least-squares collocation, spherical basis functions, etc.).

Depending on the approximations and the analysis approaches, different results (*T*-values at the same point) are obtained as there is a high sensitivity to small changes in data handling and processing. As an example, Fig. 2 shows the discrepancies along a levelling profile between the geopotential numbers (Eq. 1) obtained from 13 different gravity field modelling approaches using exactly the same input gravity data to determine W (=U + T). The individual solutions agree within $\pm 0.09\ m^2\ s^{-2}$ and $\pm\ 0.23\ m^2\ s^{-2}$ (equivalent to a physical height measure of ±0.009 m and ±0.023 m) in terms of standard deviation from the mean value. The overall discrepancies range from $-0.86\ m^2\ s^{-2}$ (−0.088 m) for solution 2 to $+0.77\ m^2\ s^{-2}$ (+0.079 m) for solution 12. The discrepancies generally show a high correlation with the topography, suggesting different responses to different approaches when dealing with the relief effects. The results presented in Fig. 2 were performed within the so-called Colorado Experiment, which represents a milestone in the comparison and calibration of different methods for the calculation of *T*. Further details about the Colorado Experiment can be found in Wang et al. (2021), Sánchez et al. (2021, 2023), and Van Westrum et al. (2021).

One possibility to minimise discrepancies between different computations would be to define a *standard* set of approximations, but this may not be appropriate as there are large differences in data availability, data density and quality around the world, hence it would not be pragmatic to define a common approach for all cases. Additionally, regions with different geographical (e.g., land only, marine and land, dominated by sea) and topography (smooth versus highly varying terrain) characteristics, which imply totally different spectral properties of the gravity field signal, require

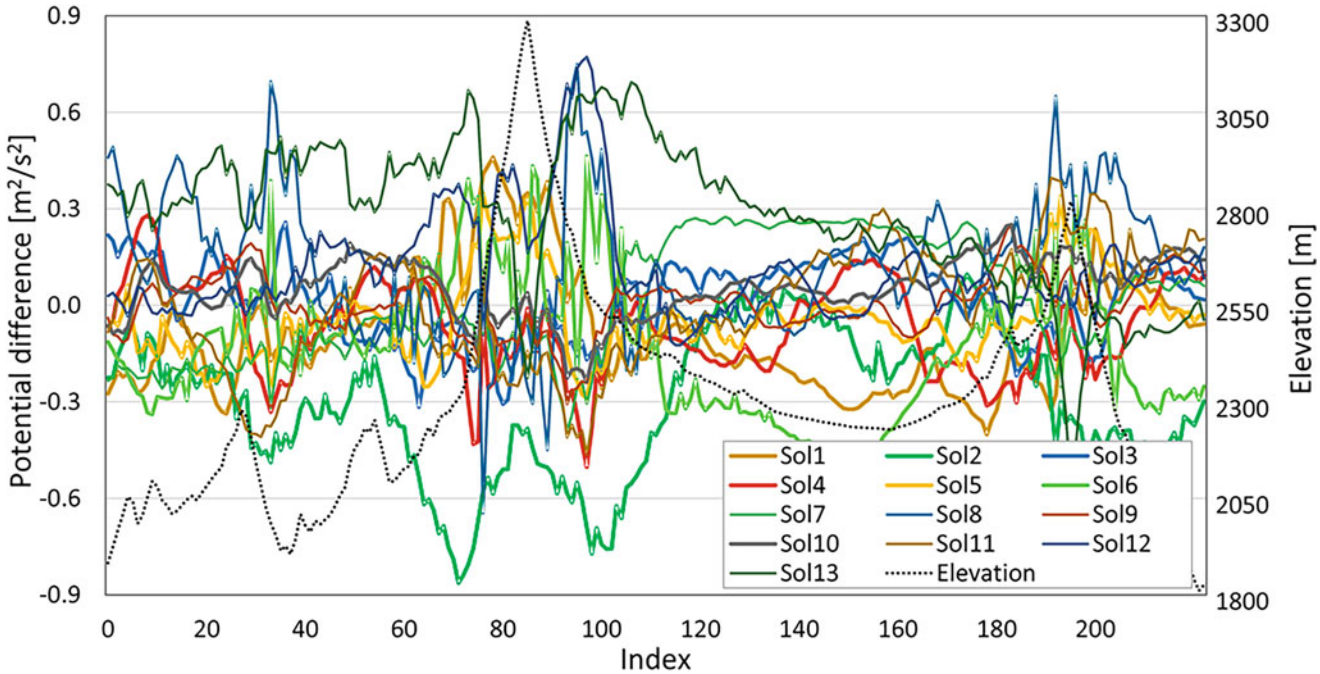

Fig. 2 Comparison of geopotential numbers obtained along a levelling profile from 13 different gravity field modelling approaches using exactly the same input gravity data to determine W

special approaches (e.g., modification of kernel functions, size of integration caps, geophysical reductions, etc.). Given the above, gravity field modelling is still to this day an *art*, meaning that the determination of potential values for each station require dedicated modelling, experience and knowledge of the area under study. Thus, it may be only possible to provide a cookbook rather than stringed guidelines for the estimation of potential values, contrary to what is the practice with the geometric component. A *centralised* calculation (as with the ITRF) is also quite complicated due to the restricted accessibility to surface gravity data. From this point of view, to take advantage of the most available gravity data for the determination of the IHRF coordinates, the potential values W required in Eq. (1) should be calculated by the regional/national experts in the geoid computation. They are knowledgeable about the particular conditions in their regions (i.e., which approximations are best suited to calculate T in their territories) and have access to unpublished surface gravity data and reference validation data (usually levelling networks co-located with GNSS (Global Navigation Satellite Systems) positioning and in some cases deflections of the vertical). In this context, the determination of the IHRF can be understood as a globally distributed calculation under the responsibility of various analysis centres, following a set of basic standards (see Sánchez et al. 2021) but with different processing schemes. This condition poses a number of organisational challenges, the most important of which are as follows:

– It is necessary to rely on colleagues who take over the responsibility for calculating the potential at each IHRF station. This could be managed through the active cooperation of IAG Sub-Commissions on *Physical Heights and Vertical Datum Unification* and the ones for *Regional Geoid Determination*, but not all the regions/countries of the world are represented. In addition, any action oriented to support the determination of the IHRF is voluntary and based on best efforts. Any resources needed have to be provided by the contributing colleagues through their home institutions (universities, agencies, research institutes, etc.). The availability of external funding is not foreseen, and everything depends on the commitment of the colleagues involved.
– Regions with less developed geodetic infrastructure lack not only surface gravity data, but also reliable know-how and computing capabilities for regional gravity field modelling. It is necessary to establish validation mechanisms that allow the quality of their results to be assessed. This is challenging because redundancy of computations is practically impossible.
– The disturbing potential T is the key quantity needed for the geoid (or height anomaly computation). Thus, the potential values W required for the IHRF geopotential numbers (Eq. 1) can be recovered from existing geoid/quasi-geoid models. However, the lack of metadata and detailed calculation reports prevents us from obtaining reliable results, while local/regional solutions are in many cases outdated and do not represent either the cur-

rent state-of-the-art in gravity field modelling and available gravity data holdings. This is particularly problematic when pure gravimetric geoid/quasi-geoid models are fitted to the existing GNSS/levelling data. This practice introduces artificial artefacts into these models in such a way that they are able to reproduce the systematic errors of the levelling networks by applying the so-called GNSS-levelling approach. It is therefore of the utmost importance to have the direct cooperation of the colleagues calculating the national/regional models, so that they provide the disturbing potential values obtained primarily from the gravity data analysis, without any fitting to GNSS/levelling data.
– It is not expected that the IHRF will be widely adopted to replace existing height systems. It is more likely that the existing height systems will continue to be used on a daily basis and that the IHRS/IHRF will only be considered for selected applications. Thus, local ties to the existing height systems will be available. In order to achieve widespread acceptance of the IHRS/IHRF, the reliability of the potential values must be drastically improved along with the adoption of geopotential-based vertical datums as best practice. Ultimately, the essential goal of the IHRF is to compute exactly the same global absolute geoid (independent of local vertical datums) with high accuracy everywhere in the world.

With this said, the next two sections are devoted to describing how the existing gravity field related IAG services could contribute to the IHRS/IHRF, and to identifying the elements needed to establish an operational infrastructure for the IHRS/IHRF that addresses the challenges described above.

4 Existing Gravity Field Related IAG Services and the IHRS/IHRF

Gravity field and geoid related data and products are collected, processed and distributed by several IAG Services, all organised under the IGFS. The IGFS acts as a clearinghouse for these Services to coordinate the standardisation, interoperability and publication of well-documented gravity field-related data and information. The following services are of particular interest to the IHRS/IHRF:

– *International Centre for Global Earth Models* (ICGEM, Ince et al. 2019): It collects, archives and publishes all existing (static and time-dependent) global gravity field models and provides web interfaces for the calculation of various gravity field functionals from the models. The monthly global gravity models calculated by the *International Combination Service for Time-variable Gravity Fields* (COST-G, Peter et al. 2022) based on the combination of GRACE/GRACE-FO data, low-low satellite-to-satellite tracking, high-low satellite-to-satellite tracking, and Satellite Laser Ranging (SLR) are available at the ICGEM as well. The ICGEM also provides global topographic models in terms of spherical harmonics. The gravity and topography models provided by the ICGEM are essential input data for the determination of the potential values needed for the IHRF coordinates, especially over areas with poor local gravity data coverage.
– *Bureau Gravimétrique International* (BGI): The BGI aims to ensure the data inventory and long-term availability of the gravity measurements taken at the Earth's surface. This includes the collection, validation, archiving, and dissemination of all types of gravity measurements (relative or absolute) acquired from land, marine or airborne surveys. The surface gravity data stored at the BGI is essential to improve the spatial resolution of the global gravity models in the determination of the potential values needed for the IHRF coordinates.
– *International Digital Elevation Model Service* (IDEMS): It maintains a catalogue of links to Digital Elevation Models (DEMs), relevant software, and related datasets (including representation of inland water in DEMs). The determination of potential values demands the appropriate handling of topographic effects, which are inferred from topography models. In addition to the global topography models provided by ICGEM, IDEMS offers an updated registry of local and regional digital elevation models of higher resolution.
– *International Service for the Geoid* (ISG, Reguzzoni et al. 2021): It collects, archives and provides regional geoid and quasi-geoid models, collects and distributes geoid determination software, and organises capacity building activities through the International School for the Determination and Use of the Geoid.

Figure 3 summarises the interaction of these Services with the IHRS/IHRF. While the first three Services (ICGEM, BGI and IDEMS) can be understood as input data providers for the determination of IHRF geopotential numbers, the ISG serves in two different ways: as a repository of the geoid or quasi-geoid models that can be computed as a *by-product* when determining T for the IHRF, and as an input data provider when geoid or quasi-geoid models are available in regions or countries that do not participate in the globally distributed IHRS/IHRF calculation. The IHRS/IHRF can also contribute additional by-products to the other Services, such as mean gravity anomaly values in regions with poor gravity data coverage in the BGI databank, or updated GNSS/levelling data sets for the evaluation of global models (ICGEM) and regional models (ISG). Similarly, for IDEMS, elevation models employed for the determination of the IHRF that are not listed in the IDEMS catalogue should be reported to IDEMS in order to extend its catalogue.

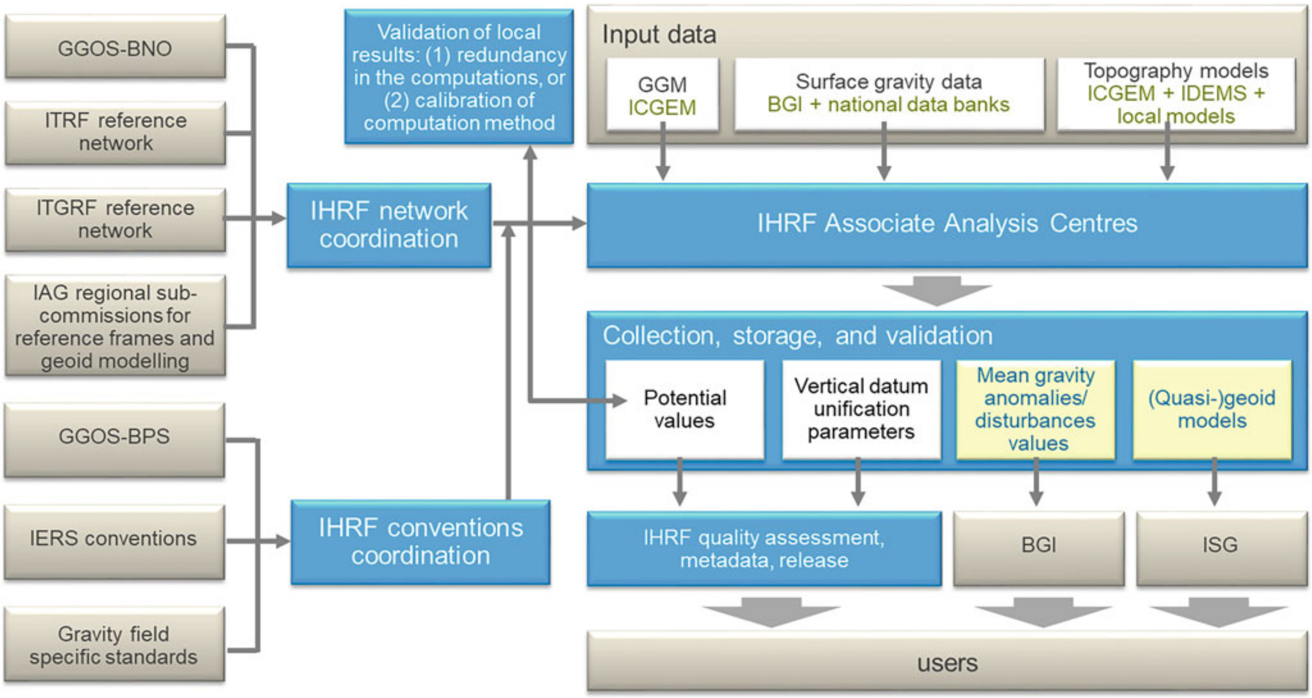

Fig. 3 Data flow between existing gravity field related IAG Services (grey boxes) and new organisational elements for the IHRS/IHRF (blue boxes)

5 Operational Infrastructure for the Long-Term Availability of the IHRS/IHRF

The operational and organisational infrastructure for the IHRS/IHRF should take care of each of the constituent elements described in Sect. 2. Our proposal is to establish a central coordinating body composed of individual modules, which will take care of specific activities as follows (see Fig. 3):

– *IHRF Coordination Centre*: It will be the central management body for the maintenance of the IHRS/IHRF. It will be responsible for the general coordination of activities required for the IHRS/IHRF and for the storage, publication, and service of the IHRF. This includes not only related documentation, products, and relevant information, but also the IHRF coordinates (X, Y, Z, C) at the IHRF reference stations and a catalogue of the vertical datum parameters; i.e., the transformation parameters between the existing local height systems and the IHRF. As in the case of the ITRF, it is foreseen that the IHRF solutions will be regularly updated to take into account new technological developments, and new and improved observation data. Our proposal is to synchronise the release of updated IHRF solutions with the release of updated ITRF solutions. This process should be also coordinated by the IHRF Coordination Centre.
– *IHRF Reference Network Coordination*: According to Ihde et al. (2017) and Sánchez et al. (2021), the IHRF reference stations should be materialised by continuously operating GNSS stations co-located with the GGOS core sites (Appleby et al. 2015), the global ITRF or its regional densifications (such as EUREF, SIRGAS, etc.), the International Terrestrial Gravity Reference Frame (ITGRF, Wziontek et al. 2021) and, if possible, with the national levelling networks. The IHRF Reference Network Coordination should implement and keep updated a catalogue of the IHRF global reference stations. This includes the decommissioning of destroyed stations and the addition of new stations to replace removed stations or improve the geographical distribution. Changes in the IHRF station distribution require interaction with the bodies responsible for the other reference frames: the ITRF (IERS), the ITGRF (IGFS), the GGOS core sites (GGOS Bureau of Networks and Observations) and the IAG Sub-Commissions for the regional reference frames and the regional geoid models. The IHRF Reference Network Coordination should also prepare and provide the set of ITRF coordinates to be used for the determination of updated IHRF solutions.
– *IHRF Conventions' Coordination*: The initial conventions, standards, and constants for the definition and realisation of the IHRS are given in the IAG Resolution 1 (2015), and further commented by Ihde et al. (2017) and Sánchez et al. (2021). These conventions, standards

and constants should be updated according to new developments in geodetic theory and technology. The IHRF Conventions' Coordination should maintain a document with the conventions and standards needed for the IHRF. Special consideration should be given to harmonisation with the conventions and standards maintained by the GGOS Bureau of Products and Standards (GGOS-BPS), the IERS Conventions (for the determination of the ITRF), and the standards used by the gravity field related IAG Services in global and regional gravity field modelling. Moreover, the IHRF Conventions' Coordination should assess the impact that revisions in the IHRF conventions will have and provide the necessary theoretical and methodological updates that need to be introduced to the existing station coordinates.

– *IHRF Associate Analysis Centres*: The IHRF Associate Analysis Centres are those national/regional agencies/bodies that contribute to the realisation of the IHRF by providing the potential values at the IHRF stations located in their countries/regions. These Analysis Centres should strictly follow the conventions outlined by the IHRF Conventions Coordination, use the ITRF input coordinates provided by the IHRF Reference Network Coordination, and provide detailed descriptions about their calculations. In an ideal data flow scheme, the IHRF Associate Analysis Centres would provide the IHRF Coordination Centre with the following products: potential values at the IHRF reference stations; vertical datum parameters; mean gravity anomalies or disturbances; and regional geoid or quasi-geoid models of high resolution. The mean gravity anomalies (or disturbances) and the geoid/quasi-geoid models would then be managed by the BGI and ISG, respectively.
– *IHRF Combination Coordination*: The IHRF Combination Coordination will be responsible for the combination and quality assessment of the regional/national solutions and for releasing the final (official) IHRF solution. The quality assessment can be based on redundant calculations or by calibration of computation methods. In the first case, at least two Associate Analysis Centres independently determine the potential values for the same stations. In the second case, IHRF Associate Analysis Centres should determine potential values using a certain set of input data and compare their results with those obtained by other processing approaches. For this purpose, the input gravity and topographic data, the GNSS/levelling validation data, and the different geoid/quasi-geoid models produced within the Colorado Experiment are available from the ISG and can be used as a basis to evaluate any disturbing potential calculation method or software anywhere.

The IHRF Reference Network Coordination, Conventions' Coordination, Associate Analysis Centres and Combination Coordination should report to the IHRF Coordination Centre, which, in turn, would report directly to the IGFS Central Bureau (Fig. 4). The IGFS presented this proposal to the IAG Executive Committee at its meeting on 10 December 2023 and it was unanimously approved. Thus, a new component of the IGFS dedicated to the IHRF has been created and will ensure the long-term availability and reliability of the IHRF.

6 Summary

The establishment and maintenance of a global height system such as the IHRS is only possible within a structured, comprehensive and global organisation such as the IAG. The efforts of the GGOS FA-UHS, IAG Commissions 1 and 2, ICCT and IGFS over the last 12 years have made it possible to pave the scientific foundations of the IHRS, to compile a cookbook for the implementation of the IHRF, and to generate a first solution for the IHRF. In particular, the availability of the input data and the results of the Colorado Experiment provide an unprecedented basis for the evaluation of gravity potential (geoid and quasi-geoid) calculation methods. Much progress has been made and continuity must be ensured to guarantee the maintenance and availability of the IHRF in the long term. Following IAG practice, the IAG Commissions, ICCT, working and study groups, etc., are responsible for the development of theory and methods, and the IAG Services operates as centres for standards, networks, data, analysis/combination and products. Our proposal is to establish an IHRF Coordination Centre reporting directly to the IGFS Central Bureau, to coordinate the operational activities necessary for the long-term availability and sustainability of the IHRF. The IGFS presented this proposal to the IAG Executive Committee at its meeting on 10 December 2023 and it was unanimously approved. Thus, a new component of the IGFS dedicated to the IHRF has been created and will ensure the long-term availability and reliability of the IHRF.

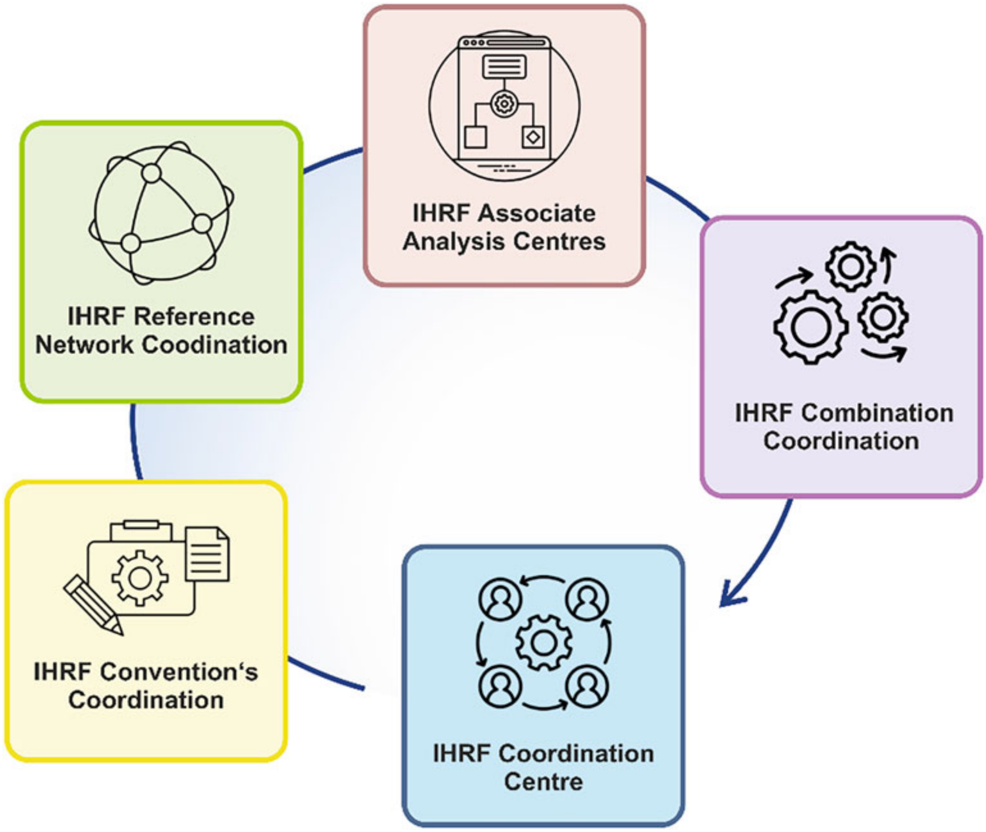

Fig. 4 Data flow between the IHRF Coordination Centre and its modules

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