GGOS Focus Area 1: Unified Height System
Present activities

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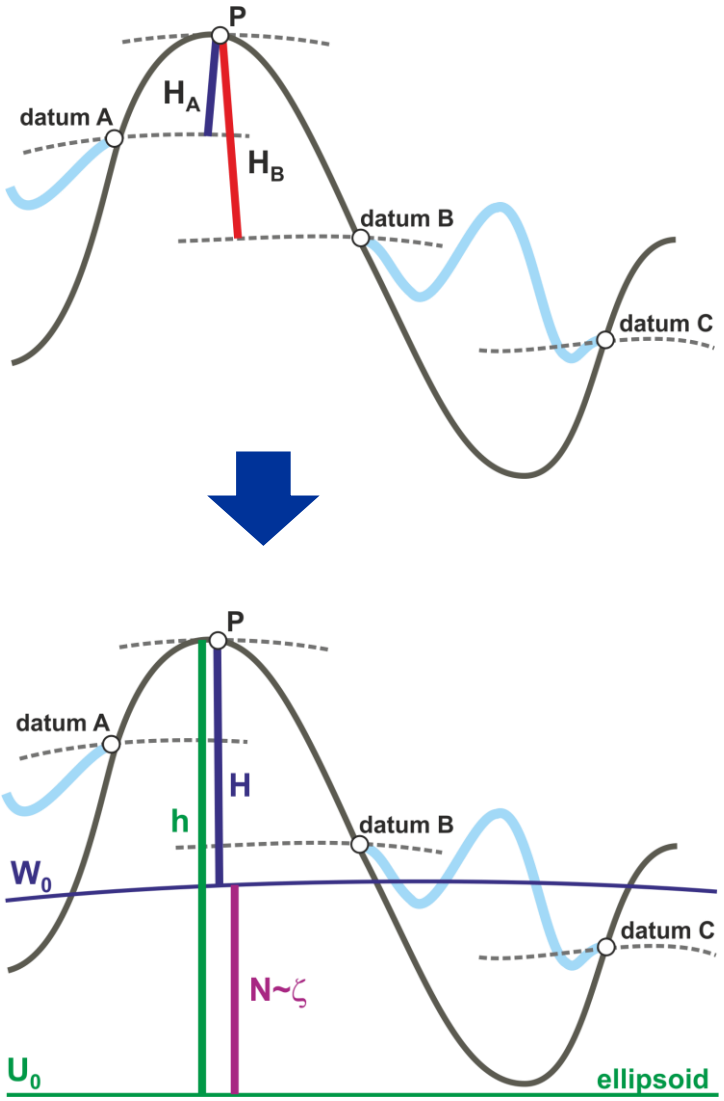
GGOS Focus Area 1: Unified Height System

- Established in 2011
- Past chairs: M. Sideris (Canada), J. Ihde (Germany)
- Objective: definition and realization of a global vertical reference system that supports
  - geometrical and physical heights with centimetre precision in a global frame;
  - the unification of all existing physical height systems (all geopotential differences referring to one and the same surface with potential W_0); and
  - high-accuracy and long-term stability of the vertical coordinates.



GGOS FA1: activities
(as in Geodesist's Handbook 2012)

- Short-term activities:
  - To establish a global vertical reference surface and its potential value W_0.
  - Refinement of standards and conventions for the definition and realization of a world height system.

- Mid-term activities:
  - To develop GGOS products for the realization of a world height system: reference frame, global height system unification, registry and metadata of existing height systems.

- Long-term activities:
  - To maintain and use in practice the world height system: temporal changes, update of definition and realization according to new geodetic developments, servicing the vertical datum needs to other geosciences.

GGOS-FA1: short-term actions (2011-2015)

- Establishment of a global vertical reference level by means of a conventional reference W_0 value.

- WG "Vertical Datum Standardisation": Estimation of a W_0 value based on the newest geodetic models, including reliability assessment.

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- Background: activities of the IAG ICP1.2: Vertical Reference Systems, 2003-2011 (Ihde et al. 2007, 2011).
- Main contributions:
  - Recommendations of the IAG Ad-hoc group on an International Height Reference System – IHRS (Ihde et al. 2015)
  - BPS Inventory of Standards and Conventions used for the IAG Products (Angermann et al. 2016).
  - Activities under the ESA project "HSU with GOCE" (Rummel et al. 2014).

GGOS-FA1: short-term actions (2011-2015)

- Establishment of a global vertical reference level by means of a conventional reference W_0 value.

- Refinement of standards and conventions for the definition and realization of a world height system.

Main result:

IAG Resolution for the Definition and Realization of an International Height Reference System (IHRS) released in July 2015.

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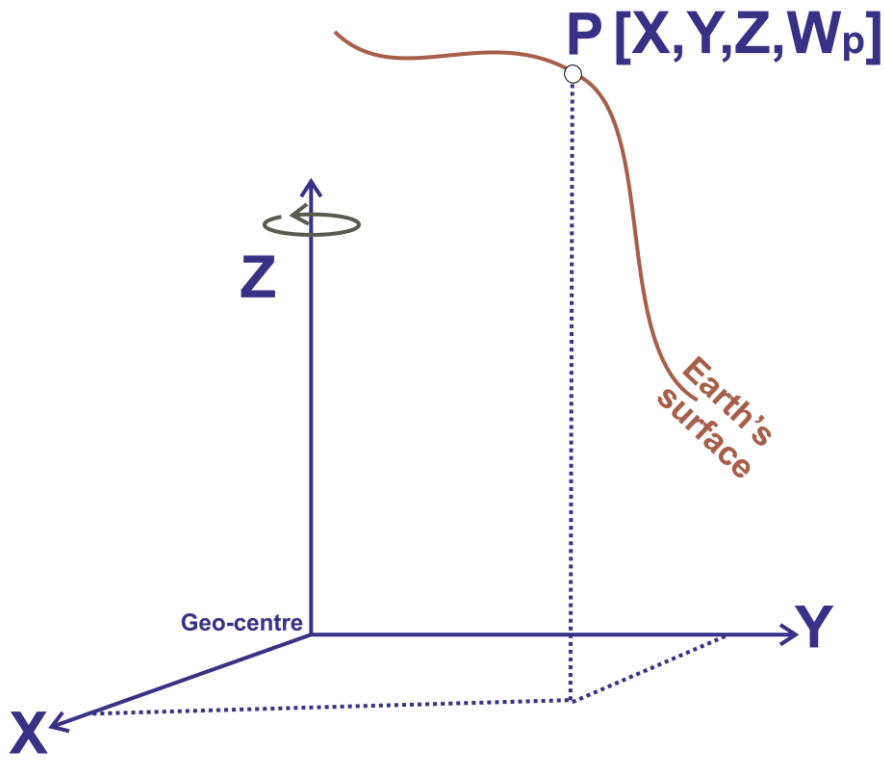
International Height Reference System (IHRS)
IAG Resolution No. 1, Prague, July 2015

1) Geopotential reference system co-rotating with the Earth.
2) Coordinates of points attached to the solid surface of the Earth are given by
   - geopotential values $W(\mathbf{X})$ (and their changes with time $\dot{W}$), and
   - geocentric Cartesian coordinates $\mathbf{X}$ (and their changes with time $\dot{\mathbf{X}}$) in the ITRS.

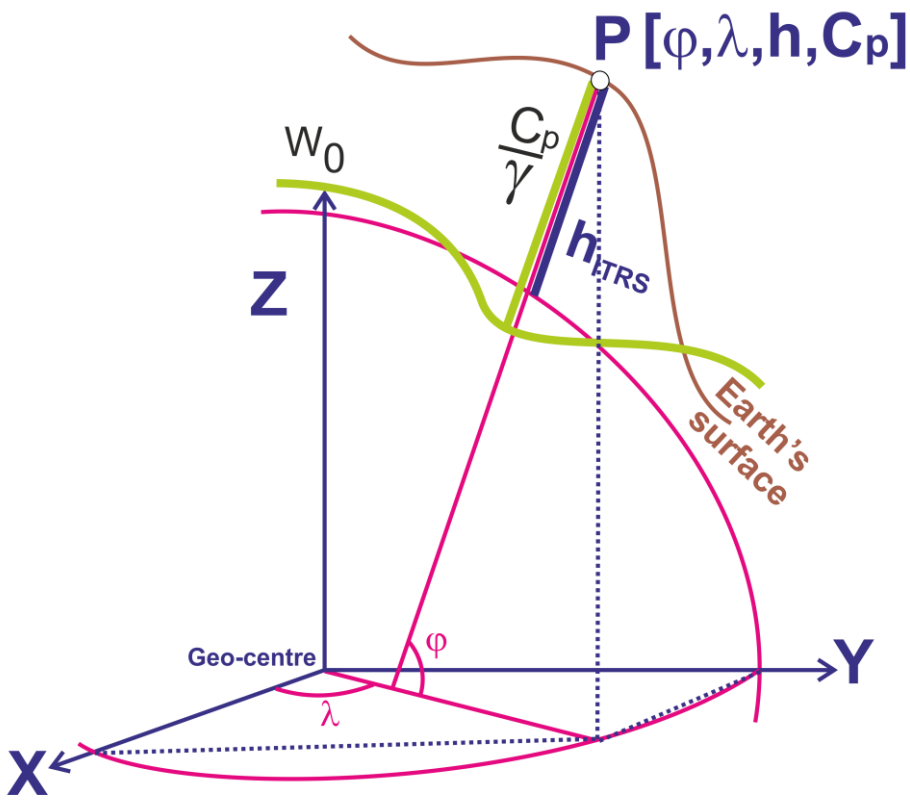


The name "International Height Reference System" unifies/standardizes all the names used previously: World Height System, Global Vertical Reference System, Global Height System, Unified Height System, Global Vertical Datum, etc.

International Height Reference System (IHRS)
IAG Resolution No. 1, Prague, July 2015

For practical purposes, potential values $W(\mathbf{X})$ and geocentric positions $\mathbf{X}$ are to be transformed into vertical coordinates with respect to a reference level:

1) geometrical component
   - $h(t_0,\mathrm{X})$; $dh(\mathrm{X})/dt$
   - conventional level ellipsoid
     $U_0 = const.$
2) physical component
   - $C_p(t_0,\mathrm{X})$; $dC_p(\mathrm{X})/dt$
   - conventional fixed value
     $W_0 = const. = 62\,636\,853.4\ \mathrm{m^2 s^{-2}}$



Estimation of primary coordinates: $\mathbf{X}_P$, W_P

$\mathbf{X}_P$

- geometric techniques (VLBI, SLR, DORIS, GNSS).

  → accuracy: some mm up to cm (ITRF coordinates).

W_P

- Levelling + Gravimetry: $W_P = W_0 - C_P$

  → Problem: local vertical datums, different gravity reductions, systematic error in levelling, etc.

  → Relative accuracy: some mm, *absolute* accuracy: up to ±2 m.

- Geodetic boundary value problem (geoid computation): $W_P = U_P + T_P$

  → Problem: different standards, restricted accessibility to the gravity data, etc.

  → Accuracy: some cm up to dm.

- Global Gravity Model + ITRF coordinates: $W_P = f(\mathbf{X}, GGM)$

  → Problem: different standards, spatial resolution (mean and short wavelengths).

  → Accuracy: some dm up to m (some cm expected, if high-resolution GGMs available).

GGOS-FA1: Main challenge presently

- Realization of the IHRS; i.e. establishment of an International Height Reference Frame (IHRF) with high-precise primary coordinates $\mathbf{X}_P$, W_P
- We suggest to follow the same hierarchy as the ITRF:
  - a global network with
  - regional and national densifications.
- This network shall be collocated with:
  - fundamental geodetic observatories (to make feasible the connection between position vectors $\mathbf{X}$, gravity potential W, international atomic time TAI, and absolute gravity $\mathbf{g}$);
  - continuously operating reference stations (to detect deformations of the reference frame);
  - geometrical reference stations of different densification levels (presumable with GNSS to allow access to the IHRF also in remote areas);
  - reference tide gauges and national vertical networks (for the vertical datum unification);
  - gravity reference stations.

GGOS-FA1: medium-term actions (2015-2019)

- Proposal for the establishment of the International Height Reference Frame (IHRF)

- Detailed standards and conventions required to establish an IHRF consistent with the IHRS definition.
- Requirements for the IHRF reference stations.
- Strategy for collocation of IHRF stations with existing geometrical reference stations at different densification levels (ITRF and regional densifications).
- Processing strategies for the precise determination of W_P, including reliability assessment.
- Approaches for the vertical datum unification.
- To identify the geodetic products associated to the IHRF and to describe the elements to be considered in the corresponding metadata.

GGOS-FA1: medium-term actions (2015-2019)

- Proposal for the establishment of the International Height Reference Frame (IHRF)

Expected main result:

A document similar to the IERS conventions; i.e., a sequence of chapters describing the components to be consider for the precise and sustainable realization of the IHRS and its practical utilization

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- Processing strategies for the precise determination of W_P, including reliability assessment.
- Approaches for the vertical datum unification.
- To identify the geodetic products associated to the IHRF and to describe the elements to be considered in the corresponding metadata.

Working Group on the Strategy for the Realization of the International Height Reference System (IHRS)

- Term 2016 – 2019
- Reports to GGOS Focus Area 1
- Contributors
  - GGOS Focus Area 1
  - International Gravity Field Service (IGFS)
  - IAG Commission 2 (Gravity field)
  - IAG Commission 1 (Reference Frames)
  - IAG Inter-commission Committee on Theory (ICCT)
  - Regional vertical reference systems
- Interaction/agreement with
  - GGOS Bureau of Products and Standards
  - IAG Joint Working Group Establishment of the GGRF
  - IGS Working Group TIGA (GNSS Tide Gauge Benchmark Monitoring)

Working Group on the Strategy for the Realization of the International Height Reference System (IHRS)

- 29 members:

  L. Sánchez (chair, Germany), J. Ågren (Sweden), M. Amos (New Zealand), R. Barzaghi (Italy), J. Boumann (Germnay), S. De Freitas (Brazil), W. Featherstone (Australia), T. Gruber (Germany), J. Huang (Canada), J. Ihde (Germany), G. Liebsch (Germany), J. Mäkinnen (Finland), U. Marti (Switzerland), P. Novak (Czech Republic), M. Poutanen (Finland), D. Roman (USA), D. Smith (USA), M. Véronneau (Canada), Y. Wang (USA), M. Blossfeld (Germany), J. Böhm (Austria), X. Collilieux (France), M. Filmer (Australia), B. Heck (Germany), R. Pail (Germany), M. Sideris (Canada), G. Vergos (Greece), C. Tocho (Argentina), D. Avalos (Mexico).

- Next meeting during the Symposium “Gravity, Geoid and Height Systems” 2016 (GGHS2016), September 19-23, Thessaloniki, Greece.

GGOS-FA1: long-term actions (2018?)

- Maintenance and use in practice of the IHRS/IHRF

- Precise modelling of the time-dependent changes of the vertical coordinate (which also reflect time variations of $\mathbf{X}$ and W).
- Organizational and operational infrastructure required to maintain the IHRF and to ensure its sustainability.
- Update the IHRS definition and realization as needed, based on future improvements in geodetic theory and observations.
- Servicing the vertical datum needs for other geosciences (e.g. hydrography and oceanography).

Possible recommendation: An “International Height Reference System Service”

Final comments

- Main achievement of GGOS-FA1 up to now: the IAG Resolution for the definition and realization of an International Height Reference System (IHRS) released in July 2015.
- Present activity: Implementation of a suitable strategy for the realization of the IHRS.
- First results to be discussed during the Symposium "Gravity, Geoid and Height Systems" 2016 (GGHS2016), September 19-23, Thessaloniki, Greece.