Global Geodetic Observing System
of the International Association of Geodesy

STATUS REPORT April 6, 2013

Theme 1: Unified Global Height System

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Present Status and Progress

- **Joint Working Group 0.1.1: Vertical Datum Standardisation**
  - Global W_o computations by four different groups delivered very close results (around 62 636 854 m^2s^{-2}), but there are still differences of about 0.5 m^2s^{-2} (~ 5 cm). It is necessary to start defining the standards and conventions for a formal recommendation on W_o
  - Web site: http://whs.dgfi.badw.de
  - Attachments: Short current status report by L. Sanchez and report by J. Ihde of the joint WG meeting held during the *Int. Symposium on Gravity, Geoid and Height Systems* in Oct. 2012
- **ESA project STSE – GOCE+: Height System Unification with GOCE**
  - Unification of North American, European and North Atlantic Datum
    - Studies of regional W_o determination, datum offsets estimation, GOCE and other EGM contributions, effects of: local data/omission errors, data biases and noise, ocean models, EGM truncation, benchmark/tide gauge spacing and distribution
    - Results published online in Special Issue on Regional and Global Geoid-based Vertical Datums of the *Journal of Geodetic Science,* Issue 4 (Dec. 2012), pp. 246 - 376, http://www.degruyter.com/view/j/jogs.2012.2.issue-4/issue-files/jogs.2012.2.issue-4.xml
  - Web site: www.goceplushsu.eu
  - Attachments: Preface and list of papers of the Special Issue of the JGS
- **Canada (GSD), Mexico (INEGI), USA (NGS) - NA vertical datum unification plans**
  - Selected the W_o in the ERS Conventions (based on tide gauge fit in NA)
  - Implementation:
    - Canada: will adopt geoid-based datum this November
    - USA: will adopt geoid-based datum in 2022
  - Web sites: www.ngs.noaa.gov/heightmod/ &

    www.nrcan.gc.ca/earth-sciences/geography-boundary/spatial-referencing/height-reference-system/modernization/5664
- **Germany (BKG and DGFI) - European vertical datum unification**
  - Ongoing research work
  - Official plans for implementation?

Planned Actions and Milestones

- **Joint Working Group 0.1.1: Vertical Datum Standardisation**
  - Formal recommendation of adoption of a new global Wo value by the IAG based on additional studies of
    - Combination of a "geodetic" sea surface model and an "oceanographic" DOT model to reproduce a sea surface closer to an equipotential surface (geoid)
    - Integration of polar regions on the Earth's surface representation
    - Differences between W_o values obtained from a long-term mean sea surface model and yearly mean sea surface models
  - A formal procedure for proper error propagation
- **ESA project STSE – GOCE+: Height System Unification with GOCE**
  - Completion of the assessment of GOCE's contributions to HSU
  - Recommendation of HSU procedures
    - for well surveyed (large and small) regions
    - for poorly surveyed areas
    - across the ocean
  - Production of a roadmap for regional and global height datum unification

Open problems

- **Data, procedures, standards, policies**
  - Lack of standards and conventions for physical heights
  - Inconsistencies between physical and geometric heights (e.g., tide systems) – Insufficient collaboration between "geometric" and "gravimetric" Services
  - Uncertainties with respect to data biases, accuracies, gross errors, reference epochs, reference surfaces, temporal changes
  - Acceptable global realization of the surface of potential W_o
  - Governments unready to accept new height datums (and thus new elevation values), especially where social issues may arise (e.g., in coastal regions, flood-prone regions)
- **Difficulty in attracting broad international participation in the work of Theme 1**
  - Groups work in this area only if (a) they have either their own individual research funding or (b) are jointly funded by government or other sources (such as ESA)
  - Though VERY difficult, GGOS should maybe consider the possibility of supporting its Themes in attracting funding for their work, through its connections with
    - GIAC, National Geodetic Surveys, Space agencies
    - Some of the IAG Services (??)
    - Other sources (international development organizations, UN, other?)

The mission of the Association is the advancement of geodesy.

IAG implements its mission by:

- advancing geodetic theory through research and teaching,
- collecting, analysing and modelling observational data,
- stimulating technological development, and
- providing a consistent representation of the figure, rotation and gravity field of the Earth and planets, and their temporal variations.

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Since the predecessor of the IAG, the 'Mitteleuropäische Gradmessung', was established back in 1862, IAG is celebrating its 150th anniversary in 2012. Celebrations will climax in September 2013 at the IAG Scientific Assembly in Potsdam, Germany. This location is particularly significant since the first ever meeting, in April 1862, was organised by General Baeyer, as representative of the Kingdom of Prussia, in Berlin. The participants were several geodesists from the Kingdom of Saxony and the Austrian-Hungarian Empire.

Gravity, Geoid and Height Systems

Participants at the GGHS2012 symposium.

In October 2012, IAG Commission 2 'Gravity Field' organised the 'Gravity, Geoid and Height Systems' (GGHS2012) symposium, assisted by the International Gravity Field Service (IGFS) and the Global Geodetic Observing System (GGOS) Theme 1 'Unified Global Height System'. The symposium took place on the island of San Servolo in the Venetian Lagoon, Italy, and the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale – which is the current Central Bureau of the IGFS – was responsible for the local organisation. The event attracted 140 participants, including 30 students.

GGHS2012 was the fifth in the series of four-yearly conferences organised by IAG Commission 2 since 1996. The conference covered all Commission 2 activities except topics related to satellite altimetry, these were covered in a separate symposium in Venice two weeks prior to GGHS2012, called '20 Years of Progress in Radar Altimetry', in Venice two weeks prior to GGHS2012.

89 oral papers and 64 posters were presented in eight sessions. Peer-reviewed proceedings of the conference will soon be published in Springer's IAG Symposia series (Volume 140). A highlight of the conference was presentation of the results of the very successful satellite gravity missions GRACE and GOCE, and in particular their applications in oceanography, mass transport and solid Earth modelling, hydrology and the atmospheric sciences. Special attention was paid to results dealing with the loss of ice mass over Greenland and Antarctica and the resulting global sea-level rise. Since the GRACE and GOCE missions are due to end soon, another important topic of GGHS2012 was the prospect for continuation of gravity space missions. Fortunately it appears that plans for a GRACE follow-on mission are progressing well, involving a collaboration of American and European space agencies, with a possible launch date of 2017.

The Joint Working Group 'Vertical Datum Standardization' coordinated a meeting of those working on the realisation of a Global Height System (GHS). They presented their results of estimating the global vertical reference level parameter W0. The individual results are now in good agreement, in the order of a few centimetres of each other. This implies that agreement on the conventional value for W0 is close. This is a prerequisite to the definition of a GHS which can be presented for broad comment, and ultimately adopted by the scientific and geospatial communities. The development of a practical definition (and realisation) of the GHS has been an important goal of the geodetic gravity community for many years. The GHS will complement the purely 3D/geometric International Terrestrial Reference System (ITRS).

Another open issue of the gravity community is the replacement of the outdated International Gravity Standardisation Network IGSN-71 by the use of modern absolute measurements and time series of super-conducting gravimeters, through international comparison campaigns of absolute gravimeters. These activities will be progressed within the corresponding working groups over the next few years. ◀

Urs Marti

MORE INFORMATION
www.iag-aig.org
www.gravityfield.org
www.iag-commission2.ch

Joint Working Group (JWG) 0.1.1

Vertical Datum Standardisation

Meeting Summary

Date October 11, 2012, 6:30 pm

Place San Servolo Island, Venice. JWG 0.1.1 Meeting in the frame of the International Symposium on Gravity, Geoid and Height Systems GGHS 2012

Attendees

JWG 0.1.1 Members: D. Roman (USA), J. Ågren (Sweden), J. Huang (Canada), L. Sánchez (Germany), R. Čunderlik (Slovakia), V. Vatrt (Czech Rep.), Y.M. Wang (USA), Z. Minarechová (Slovakia), Z. Šíma (Czech Rep.).

Guests: A.P. Falcão (Portugal), C. Tocho (Argentina), D. Avalos-Navarro (Mexico), D. Ruess (Austria), H. Drewes (Germany), H. Wilmes (Germany), J. Mäkinen (Finland), L. Fenoglio (Germany), M. Amos (New Zealand), M. Mojzes (Slovakia), M.C. Pacino (Argentina), P. Holota (Czech Rep.), R. Forsberg (Denmark), R. Grebenitcharsicy (UK), S. Valcheva (Bulgaria), U. Marti (Switzerland), W. Shen (China), Y. Juanguo (China).

Agenda

1. Introduction to the JWG 0.1.1
2. The global vertical reference level W_0
3. Local/regional realisation of the global vertical reference level
4. Website
5. Various

1. Introduction to the JWG 0.1.1

L. Sánchez presents a brief description of the JWG 0.1.1 including (see attached presentations):

- Objectives (Recommendation about the W_0 value to be officially adopted by the IAG, guidelines for realisation and usage of the recommended value)
- Relationship with other IAG components (GGOS, IAG Commissions 1 and 2, geometric Services under the umbrella of the IERS, gravity-related Services under the umbrella of the IGFS, IAS, PSMSL and the GGOS Bureau for Standards and Conventions)
- Interaction with the Working Group "Numerical Standards in Fundamental Astronomy" of the International Astronomical Union due to the dependence of the constant L_G on W_0.
- Present status in the determination of a global W_0 value.

Main conclusion: The JWG 0.1.1 shall support the implementation of the short-term items outlined by the GGOS-Theme 1 (Unified Height system), especially the Item 03 "Establishment of a global vertical reference level". This item explicitly specifies "A formal recommendation about the W_0 value to be

adopted within IAG is a responsibility of the GGOS Working Group on Vertical Datum Standardisation" (see Geodesist's Handbook 2012, Drewes et al. 2012)

2. The global vertical reference level W_0

At present, there are four groups working on the W_0 determination: the Prague Group (Vatrt et al., former Burša et al.), Bratislava Group (Čunderlik et al.), Newcastle/Latakia Group (Dayoub et al.) and the Munich Group (Sánchez et al.). When the JWG 0.1.1 was created (during the IUGG General Assembly in Melbourne, August 2011), the W_0 estimations of Čunderlik et al., Dayoub et al., Sánchez et al. were very close to each other (largest discrepancy ~0,2 m^2s^{-2}); while the estimation of Burša et al. was a little far away (about ~2 m^2s^{-2}). According to this, these four groups were invited to participate in the JWG 0.1.1 and they agreed on joining efforts to refine and compare their computations in order to

- evaluate their individual methodologies,
- establish inconsistencies between the input data,
- ensure redundancy between the different computations,
- identify possible discrepancies between the individual results,
- clarify and solve remaining disagreements between the individually computed W_0 values.

In the last months, each group repeated its computations using its own methodology but the same input data, explicitly the same mean sea surface models (CLS11, DUT10) and global gravity models (EGM2008, GOCO03S, EIGEN6C). An exception is the Burša Group, who applied its own mean sea surface model derived from recent satellite altimetry measurements. The new results were presented during the GGHS2012 symposium, resulting in the main conclusion that all the computations are now delivering very close values (including the computation of Burša et al.) and the remaining differences (~0,5 m^2s^{-2}) can be solved by outlining specific standards and conventions. (For more details regarding the individual computations please see the corresponding presentations/papers listed at the end of this summary).

According to these new results, the JWG 0.1.1 members agreed on the following:

- The W_0 value included in the IERS Conventions (and used by the IAU for the definition of the L_G constant) presents a discrepancy of about ~2 m^2s^{-2} with respect to the recent computations.
- A formal IAG recommendation regarding the best present W_0 estimate shall be outlined to replace the value included in the IERS Conventions and to be introduced as the reference level in the GGOS Unified Height System.
- The recommendation on the best estimate for W_0 shall be an agreement between (signed by) the four groups (Burša et al., Čunderlik et al., Dayoub et al., Sánchez et al.).
- The outlined recommendation shall be supported by four individual papers describing methodology and input data applied by each group. Based on these four papers, a further common summary paper shall be produced to provide an overview and the main characteristics of the W_0 estimation recommended.
- As a first report of the JWG 0.1.1, the four groups will contribute to a common paper to be published in the GGHS2012 Proceedings.
- The next activities to be carried out by the individual groups to refine their estimations and to advance in the definition of required standards and conventions shall include:

- Combination of a “geodetic” sea surface model and an “oceanographic” mean dynamic topography model to reproduce a sea surface closer to an equipotential surface (geoid);
- Integration of polar regions on the Earth’s surface representation;
- Differences between W_0 values obtained from a long-term mean sea surface model and yearly mean sea surface models;
- A formal procedure for the error propagation analysis.

3. Local/regional realisation of the global vertical reference level

One of the main objectives of the JWG 0.1.1 is to provide guidance in the practical realisation of the global W_0 at regional/local level. One possibility is the combination of geometrical and physical heights with (quasi)geoid models of high resolution, i.e. h=H-N. Although this combination is at present widely used for several purposes, it is clear that there are still too many inconsistencies between the different heights and their combination is not reliable enough for the precise realisation of any reference level. To face this inconvenience, it was asked if the JWG 0.1.1 could try to outline the basic standards to be followed by the three coordinates (h, H, N) to guarantee a consistent combination and, as a consequence, to design an appropriate realisation strategy of the global W_0. This proposal produced many pro and contra comments and it was decided to take up this discussion again once the recommendation on W_0 is ready.

4. Website: http://whs.dgfi.badw.de

L. Sánchez tries to keep a web site about the JWG 0.1.1 activities updated. This web site was initially established for the IAG Inter-Commission Project 1.2 (Vertical Reference Frames) and at present contains:

- Terms of reference of the JWG 0.1.1 (objectives, plan of activities, members, etc.)
- The ICP1.2 documents (Conventions, presentations, reports, meeting summaries, etc.)

It was proposed in this meeting to extend the content of the web site including:

- The terms of reference of GGOS-Theme 1 (because they are missing in the GGOS web page)
- A list of references with recent “vertical datum”-related publications
- Meeting presentations of the JWG 0.1.1 members, when they agree to publish their contributions in the web site.

5. Variuos

- New JWG 0.1.1 members after the GGHS2012 Symposium: C. Tocho (Argentina), R. Klees (Netherlands).

- List of presentations given by JWG 0.1.1 members at the GGHS2012 Symposium:

  Report on the activities of the working group "Vertical Datum Standardisation"
  Sánchez L., Ågren J., Čunderlík R., Dayoub N., Faskova Z., Huang J., Mikula K., Moore P., Roman D., Sima Z., Vatrt V., Vojtiškova M., Wang Y.M.

  Realization of WHS based on the static gravity field observed by GOCE
  Čunderlík R., Mikula K.

Integration of gravity data into a seamless transnational height model for North America
Roman D., Véronneau M., Avalos D., Li X., Holmes S., Huang J.

Wo improved by EGM08 / GRACE geopotential models and Jason 1, 2 altimetry
Burša M., Kouba J., šima Z., Vatrt V., Vojtiškova M.

High-resolution global gravity field modelling by finite volume method
Minarechová Z., Macak M., Čunderlík R., Mikula K.

Data fusion for geoid computation - numerical tests in Texas area
Wang Y.M., Li X.

Investigations of the requirements for a future 5 mm quasigeoid model over Sweden
Ågren J., Sjöberg L.E.

Impact of the oblique derivative on precise local quasigeoid modelling in mountainous regions
Spir R., Čunderlík R., Mikula K.

A Stokes approach for the comparative analysis of satellite gravity models and terrestrial gravity data
Huang J., Véronneau M.

Assessment of GOCE gravity field models for the new geoid-based vertical datum in Canada
Sinem Ince E., Sideris M.G., Huang J., Véronneau M.

Assessment of GOCE models over Mexico and Canada
Santos M.C., Avalos D., Peet T., Huang J., Vaníček P.

Improving the Swedish quasigeoid by gravity observations on the ice of Lake Vänern
Ågren J., Engberg L.E., Alm L., Dahlström F., Engfeldt A., Lidberg M.

On solving oblique derivative boundary-value problem by the finite volume method
Macak M., Mikula M.

- Selected publications related with the W_0 estimation:

Burša M., S. Kenyon, J. Kouba, Z. Šíma, V. Vatrt, V. Vitek, M. Vojtíšková. (2007a). *The geopotential value Wo for specifying the relativistic atomic time scale and a global vertical reference system*. J. Geod., 81: 103 – 110.

Burša M., Z. Šíma, S Kenyon, J. Kouba, V. Vatrt, M. Vojtíšková (2007b). *Twelve years of developments: geoidal geopotential Wo for the establishment of a world height system - present and future*. In: Proceedings of the 1st international symposium of the International Gravity Filed Service, Istanbul, p. 121-123.

Čunderlík R., K. Mikula, M. Mojzeš (2008). *Numerical solution of the linearized fixed gravimetric boundary-value problem*. J Geod 82: 15 – 29. DOI: 10.1007/s00190-007-0154-0. Springer.

Čunderlík R., K. Mikula (2009). *Numerical solution of the fixed altimetry-gravimetry BVP using the direct BEM formulation*. In: Sideris, M.G. (Ed.), Oberving our changing Earth, IAG Symposia 133:229-236. Springer.

Dayoub N., S.J. Edwards, P. Moore (2012). *The Gauss-Listing potential value Wo and its rate from altimetric mean sea level and GRACE*. J Geod. DOI: 10.1007/s00190-012-1547-6.

Sánchez, L. (2008). *Approach for the establishment of a global vertical reference level*. In: Xu, P., J. Liu, A. Dermanis (Eds.), VI Hotine-Marussi Symposium on Theoretical and Computational Geodesy. Springer, IAG Symposia (132): 119-125.

Sánchez L. (2007). *Definition and Realization of the SIRGAS Vertical Reference System within a Globally Unified Height System*. In: Tregoning, P., Ch. Rizos (Eds.), Dynamic planet. Springer, IAG Symposia (130): 638-645.

Sánchez L. (2009). *Strategy to establish a global vertical reference system*. In: Drewes, H. (Ed.), Geodetic Reference Frames. Springer, IAG Symposia (134): 273-278, doi:10.1007/978-642-3-00860-3-42.

- Annexes to this meeting summary:

  Report on the activities of the working group "Vertical Datum Standardisation"

  Sánchez L., Ågren J., Čunderlík R., Dayoub N., Faskova Z., Huang J., Mikula K., Moore P., Roman D., Sima Z., Vatrt V., Vojtiškova M., Wang Y.M.

  Slides for the JWG 0.1.1 meeting in the frame of the GGHS2012 Symposium.

Joint Working Group 0.1.1

Vertical Datum Standardisation

A common initiative of

GGOS Theme 1: Global Height System	International Gravity Field Service (IGFS)	IAG Commission 2: Gravity Field	IAG Commission 1: Reference Frames

Members

L. Sánchez (Germany), Chair
R. Čunderlík (Slovakia)
Z. Faskova (Slovakia)
K. Mikula (Slovakia)
N. Dayoub (Syria)
P. Moore (United Kingdom)
Z. Šima (Czech Republic)
C. Tocho (Argentina)
J. Makinen (Finnland)
R. Kless (The Netherlands)
V. Vatrt (Czech Republic)
M. Vojtiskova (Czech Republic)
J. Huang (Canada)
D. Roman (USA)
Y. Wang (USA)
J. Ågren (Sweden)

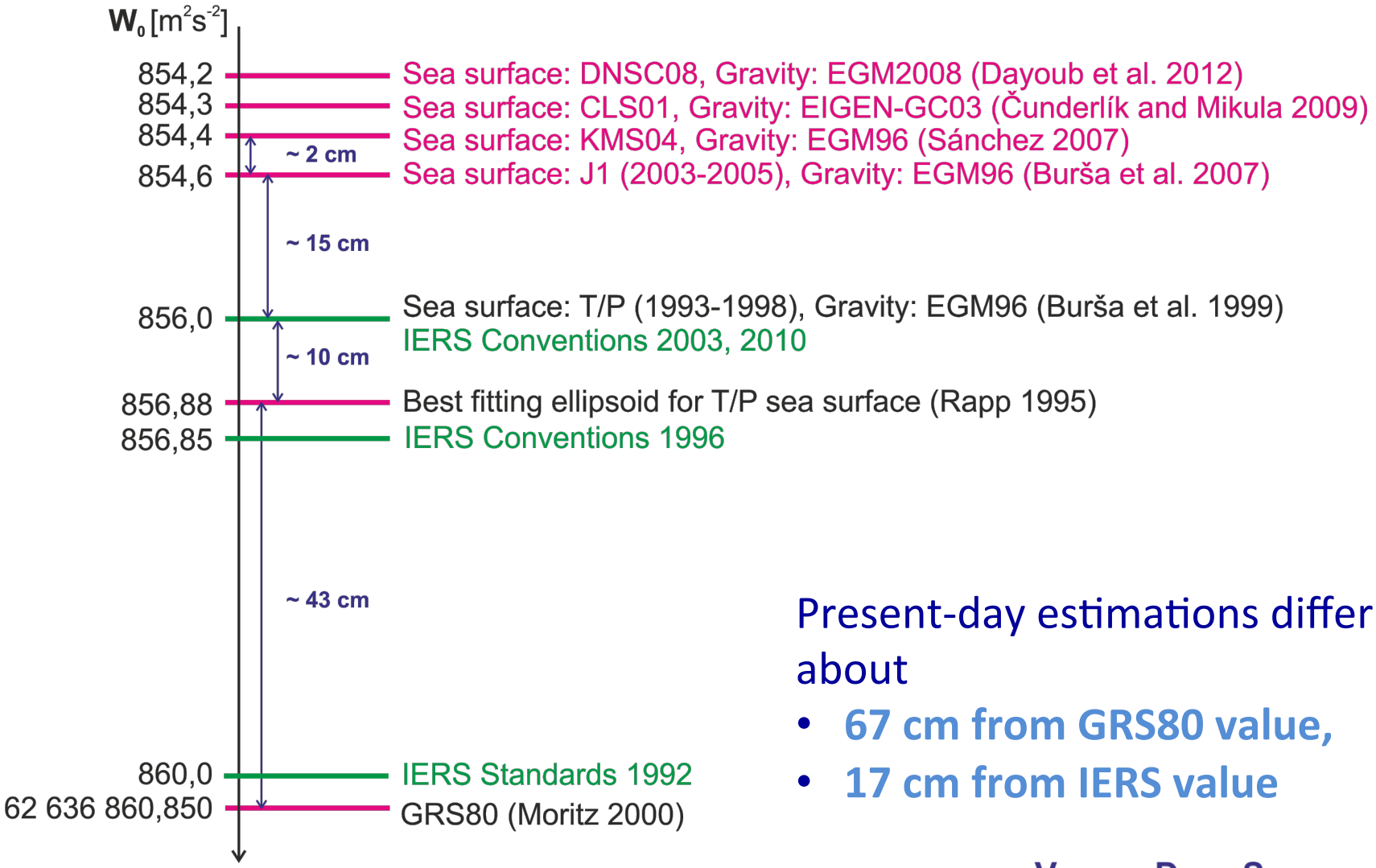
GGOS Theme 1: Short-term items (IAG Geodesist Handbook 2012)

01: Refinement of standards and conventions for the definition and realisation of a Global Unified Height System…

02: Divulgation and integration of the global height system standards and conventions within the IAG components (Commissions, Services, GGOS)…

03: Establishment of a global vertical reference level: to make a recommendation about the W_0 value to be adopted as the conventional reference level for the Unified Global Height System. This W_0 value must also be promoted as a defining parameter for the computation of an improved mean Earth ellipsoid and as a reference value for the computation of the constant L_G within the IERS conventions. **A formal recommendation about the W_0 value to be adopted within IAG is a responsibility of the GGOS Working Group on "Vertical Datum Standardisation"**, which is a joint initiative of GGOS Theme 1, IAG Commissions 1 and 2 and the International Gravity Field Service.

Some examples of W_0 values



Present-day estimations differ about

- **67 cm from GRS80 value,**
- **17 cm from IERS value**

About W_0 estimations

Status

- At present, the most accepted W_0 value corresponds to the "best estimate" available in 2004. It is included in the IERS Conventions and was computed by Burša et al. (1999).

New estimations:

- Computations started in 2005 produce four very close W_0 values (differences of about 0,2 m^2s^{-2}): Burša et al. (2007), Čunderlik et al. (2008, 2009), Dayoub et al. (2010, 2012), Sánchez et al. (2005, 2007, 2008).

What to do?

- To keep the IERS value, although it differs about ~2 m^2s^{-2} from the recent estimations?
- To recommend a (new) "best present estimate" for W_0?

WG on Vertical Datum Standardization

Objectives

- To **bring together all teams working on the computation of W_0** to elaborate an inventory describing individual methodologies, conventions, standards, and models presently applied;
- To implement **a new W_0 computation** following individual (own) methodologies, but applying the same input geodetic models;
- To make a proposal for a **formal IAG/GGOS convention about W_0** supported by a document containing the detailed computation of the recommended value.
- To provide **a standard about the usage of W_0 in the vertical datum unification** describing an appropriate strategy to connect (unify, transform) any local height system with the global W_0 reference level.

Activities faced in 2011-2012

First Results (1/3)

Different teams computed W_0 using the same input data, but their own methodologies:

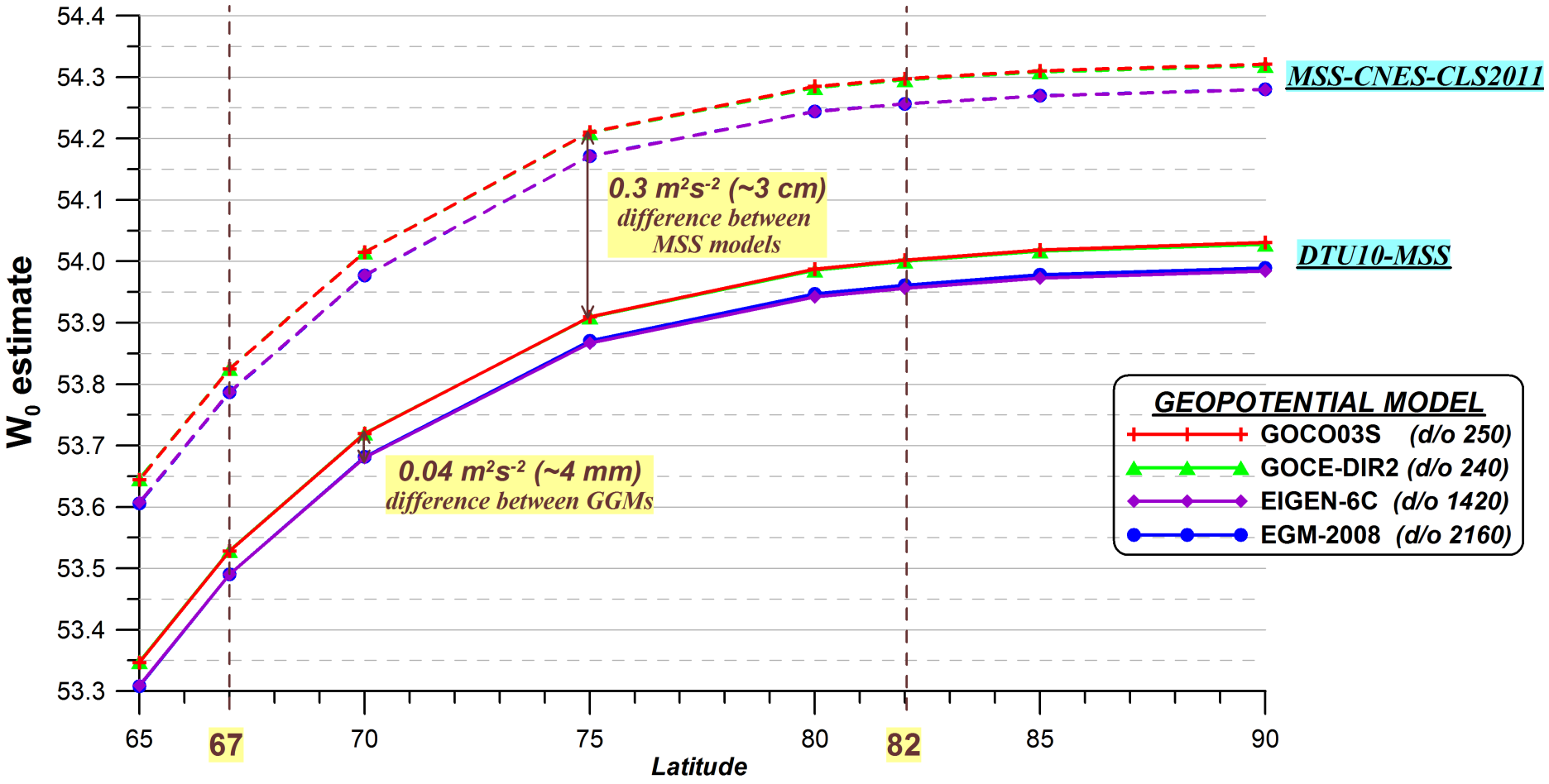
Input data

- mean sea surface models (MSS):
  - CLS11 (Schaeffer et al. 2012)
  - DTU10 (Andersen 2010)
- global gravity model (GGM)
  - EGM2008 (Pavlis et al, 2012)
  - EIGEN6C (Förste et al. 2011)
  - GOCO3S (Mayer-Gürr et al. 2012)

Analysis of

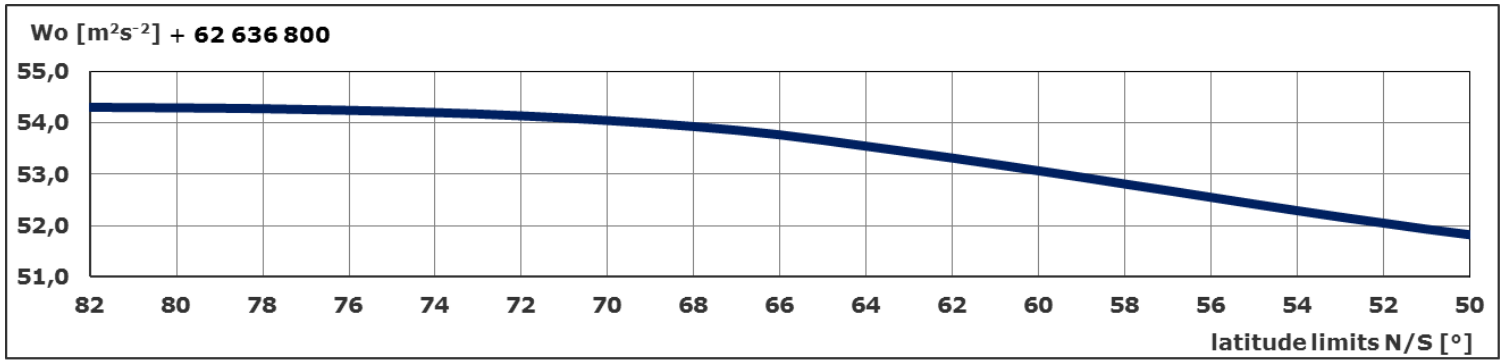
- W_0-dependence on the MSS latitude coverage.
- W_0-dependence on the retained degree n of the GGM.
- W_0-dependence on the reference epoch of the MSS and GGM.

First Results (2/3)

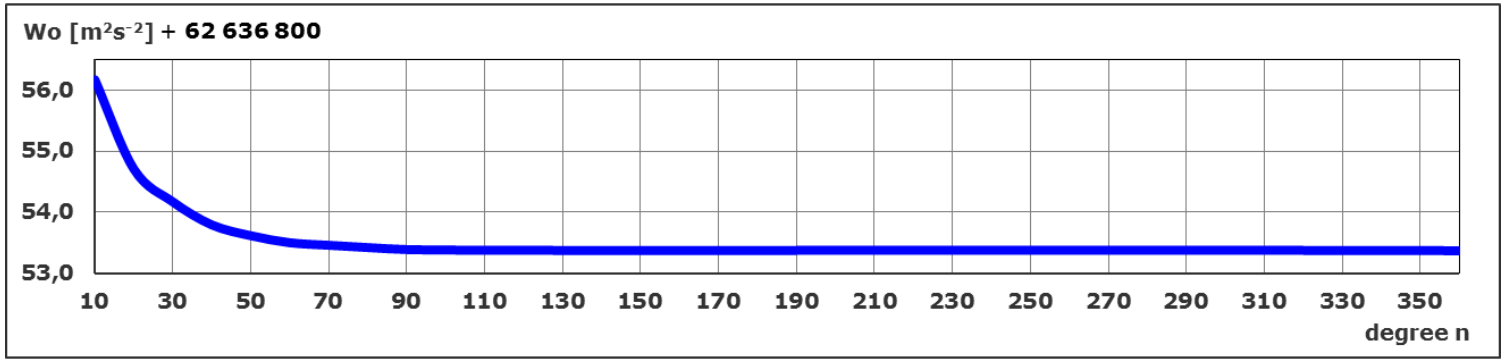


Estimates provided by R. Čunderlík, Z. Faskova, K. Mikula

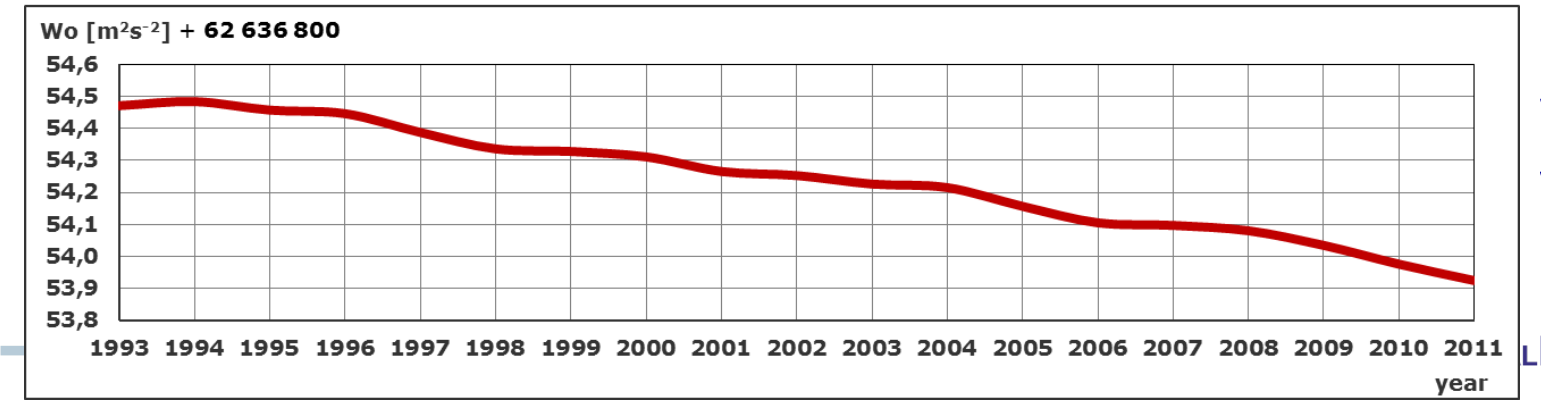
First Results (3/3)



W_0-variation with latitudinal coverage.



W_0-variation with degree *n* of the GGM.



W_0-variation with time.

Estimates provided by L. Sánchez

Conclusions and Outlook

- All the computations are delivering very close results (**around 62 636 854 m^2s^{-2}**), but there are still differences of about **0,5 m^2s^{-2}** (~ 5 cm). It is necessary to start defining the standards and conventions for a formal recommendation on W_0.
- Activities to be faced in the close future:
  - Combination of a "geodetic" sea surface model and an "oceanographic" DOT-model to reproduce a sea surface closer to an equipotential surface (geoid);
  - Integration of polar regions on the Earth's surface representation;
  - Differences between W_0 values obtained from a long-term mean sea surface model and yearly mean sea surface models;
  - A formal procedure for the error propagation analysis.

More details at http://whs.dgfi.badw.de

Journal of Geodetic Science

DOI: 10.2478/jogs-2013-0006 •

Preface to the Special Issue of the Journal of Geodetic Science on *Regional and Global Geoid-based Vertical Datums*

The idea of a Special Issue on current research on vertical datums was initially suggested by the co-investigators of the ESA-funded project *STSE – GOCE+: Height System Unification with GOCE*. Although the participating researchers had been previously presenting their work at various international conferences, it was only when they held one of their progress report meetings in Banff, Canada, that they had the opportunity to all attend and present at the same conference. This conference was the 2012 Annual Meeting of Canadian Geophysical Union (CGU), where Session G1: *Regional and global geoid-based vertical datums* was organized and convened by Dan Roman of the US National Geodetic Survey, Michael Sideris of the University of Calgary, and Marc Veronneau of the Geodetic Survey Division of Natural Resources Canada. The Journal of Geodetic Science kindly agreed to devote one of its issues to the subject of Session G1 and, therefore, the session presenters were invited to submit their papers for peer review and publication in this Special Issue. In addition, several colleagues working on vertical datums in general, including temporal effects, were also invited to contribute to the Special Issue.

All submissions were peer-reviewed by two experts in the subject. Guest editor Prof. Michael G. Sideris handled the reviewing process, with valuable help from Prof. Georgia Fotopoulos and Dr. Mehdi Eshagh. What you have in front of you are the twelve contributions accepted for publication. They cover a wide set of datum-related issues, from the theoretical definition and unification of vertical datums by the geodetic boundary value problem approach and oceanographic information, to the practical realization and testing in various parts of the world (Europe, North and South America, Atlantic Ocean, Australia). The work presented in this Special Issue is also a contribution to GGOS's Theme 1: *Global Unified Height System.*

I would like to thank all contributors, as well as the Editor-in-Chief, Prof. Lars E. Sjöberg, and the Managing Editor Dr. Mehdi Eshagh for their hospitality, help and support. Without their excellent collaboration and prompt responses, it would not have been possible to publish this Special Issue in such a timely manner.

Prof. Michael G. Sideris
Guest Editor

Calgary, January 28, 2013

Some of the participants of the CGU 2012, Session G1.

List of papers of the Special Issue of the JGS

1. Ch. Gerlach and Th. Fecher, Approximations of the GOCE error variance-covariance matrix for least-squares estimation of height datum offsets

2. T. Hayden, B. Amjadiparvar, E. Rangelova, and M.G. Sideris, Estimating Canadian vertical datum offsets using GNSS/levelling benchmark information and GOCE global geopotential models

3. T. Gruber, C. Gerlach and R. Haagmans, Intercontinental height datum connection with GOCE and GPS-levelling data

4. E. Rangelova, W. van der Wal, and M.G. Sideris, How Significant is the Dynamic Component of the North American Vertical Datum?

5. T. Hayden, E. Rangelova, M. G. Sideris and M. Véronneau, Evaluation of W0 in Canada using tide gauges and GOCE gravity field models

6. P.L. Woodworth, C.W. Hughes, R.J. Bingham and T. Gruber, Towards worldwide height system unification using ocean information

7. C. Kotsakis, A conventional approach for comparing vertical reference frames

8. L. Sánchez, Towards a vertical datum standardisation under the umbrella of Global Geodetic Observing System

9. Rülke, G. Liebsch, M. Sacher, U. Schäfer, U. Schirmer and J. Ihde, Unification of European height system Realizations

10. R. Rummel, Height unification using GOCE

11. D. Bolkas, G. Fotopoulos and M. G. Sideris, Referencing regional geoid-based vertical datums to national tide gauge networks

12. W. E. Featherstone, M. S. Filmer, S. J. Claessens, M. Kuhn, C. Hirt, and J. F. Kirby, Regional geoid-model-based vertical datums – some Australian perspectives