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), J. Mäkinen (Finland).

- 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.

Report on the activities of the Working Group

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

Initial members

L. Sánchez (Germany), chair	
R. Čunderlík (Slovakia)	V. Vatrt (Czech Republic)
Z. Faskova (Slovakia)	M. Vojtiskova (Czech Republic)
K. Mikula (Slovakia)	J. Huang (Canada)
N. Dayoub (Syria)	D. Roman (USA)
P. Moore (United Kingdom)	Y. Wang (USA)
Z. Šima (Czech Republic)	J. Ågren (Sweden)

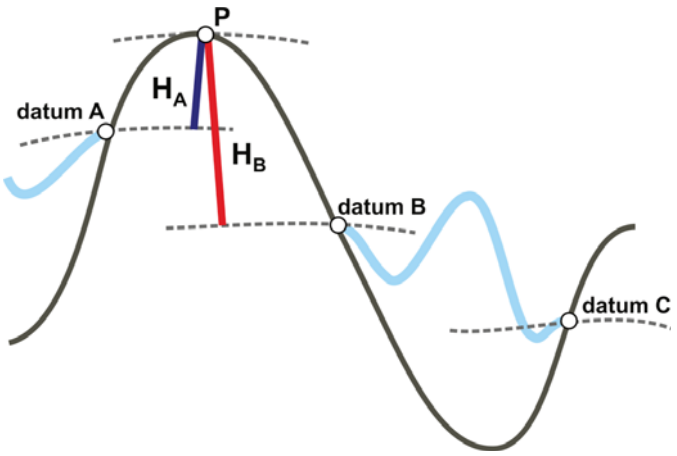
Motivation 1: inconsistent height systems

The Global Geodetic Observing System (GGOS) requires geodetic reference frames with

- an order of **accuracy higher** than the magnitude of the phenomena and effects we want to study (e.g. global change);
- **consistency** and **reliability worldwide**;
- **long-term stability**.

The existing height systems

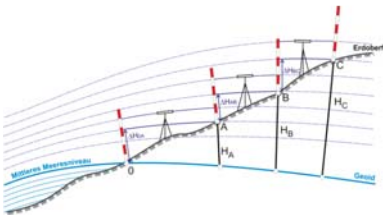
- refer to **different levels** (many [dm] of discrepancy);
- realise **different types of heights** (normal, orthometric, etc.);
- omit (sea and land) **vertical variations** with time;
- do not support the precise combination of **h-H-N (= ?)**



Motivation 2: new methods for height determination

Today

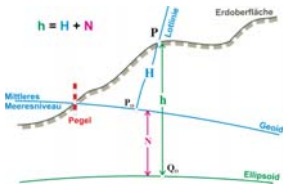
Levelling in combination with gravity reductions



$$C(g,dn) = W_0 - W_P = \int_0^P g\,\delta n \cong \sum_0^P g\,dn$$

Desired

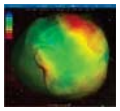
Disturbing potential in combination with a reference ellipsoid



$$C(U_0,T) = -(U_0 - W_0) + \bar{\gamma}(\varphi)h - T(\varphi,\lambda,h)$$

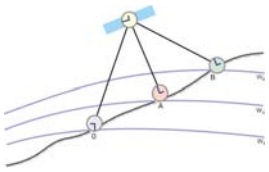
In the future

Global gravity field models in combination with ITRS/ITRF coordinates



$$C(\bar{C}_{nm},\bar{S}_{nm}) = W_0 - [V(r,\theta,\lambda) + Z(r,\theta)]$$

Comparison of clock frequencies of high-precision



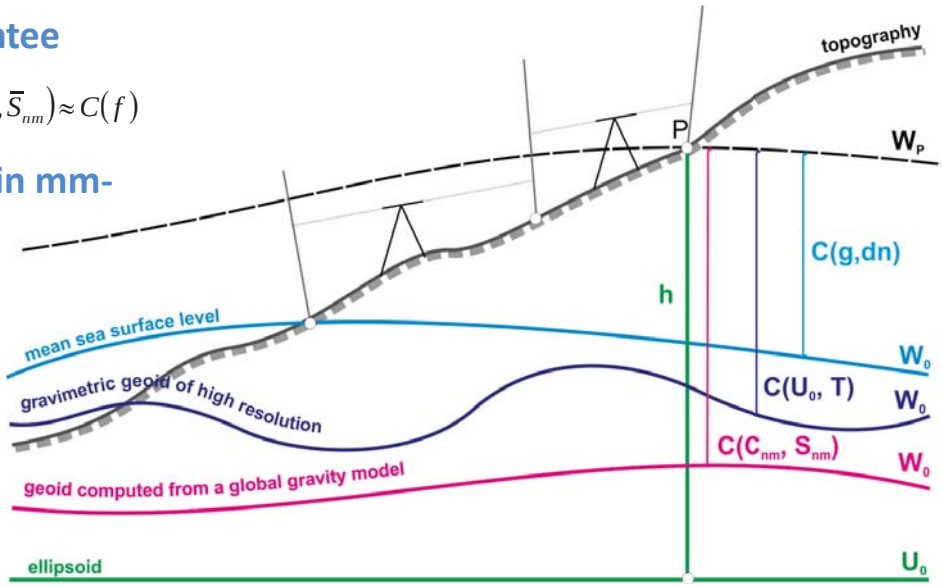
$$C(f) = c^2\left(\frac{f - f_0}{f_0}\right)$$

Reference level depending on input data?

How can we guarantee

$$C(g,dn) \approx C(U_0,T) \approx C(\bar{C}_{nm},\bar{S}_{nm}) \approx C(f)$$

in cm-level (better in mm-level), globally ?

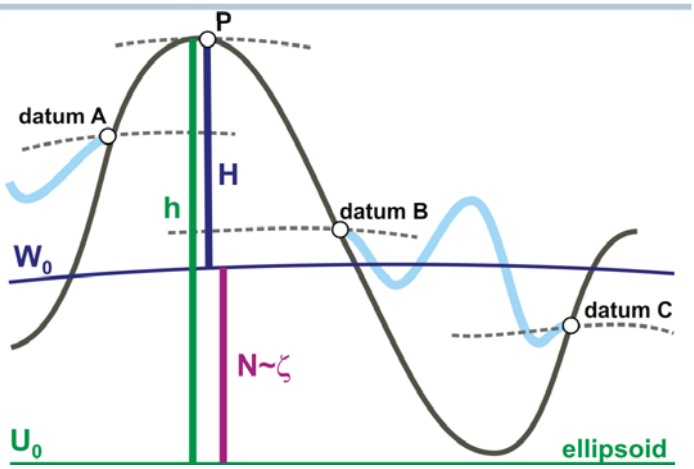


- The same W_0 value for all existing (regional) geoids?
- The same geoid with different (regional) W_0 values?
- Only one geoid with only one W_0 value?

Solution

A global vertical reference system

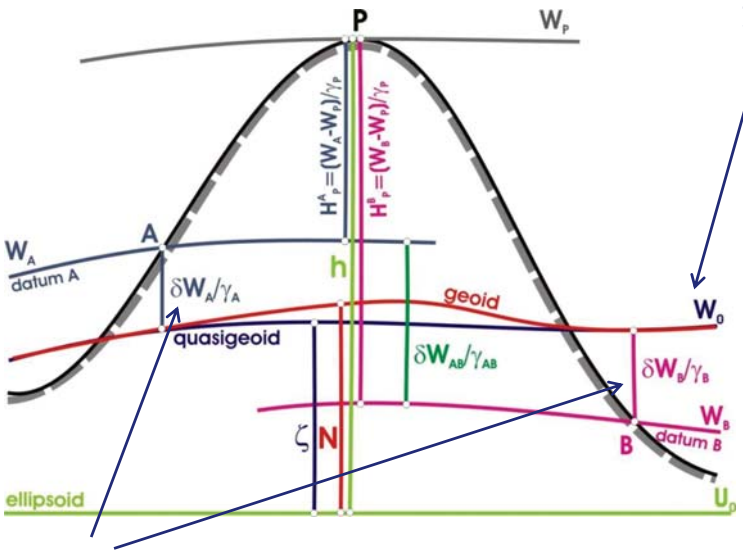
- To solve the **discrepancies** between the **existing height systems** and
- To support the **different** techniques for **height determination**.



Implicit characteristics:

- One reference level (W_0 or geoid) to be used globally;
- All existing geo-potential numbers (physical heights) referring to one and the same global level;
- Precise combination with geometric heights and geoid models of high resolution, i.e. h-H-N=0.

Strategy



1. Selection (**Definition and realisation**) of a global reference level W_0
   - W_0 = potential of the geoid
   - Geoid = equipotential surface best fitting the global mean sea (Gauss definition)

GGHS 2012, Section 5 (Thursday morning)

2. Connection of the individual reference levels with the global W_0
   - Basic approach: $h - H - N = \frac{\delta W}{\gamma}$

GGHS 2012, Section 5 (Wednesday afternoon)

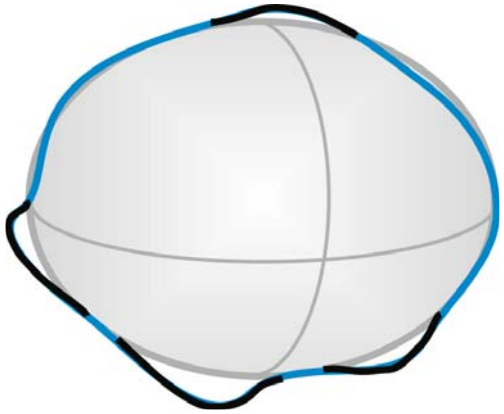
Poster session today and tomorrow!

Empirical estimation of W_0

In the 1990s and before:

- Determination of the parameters for a best fitting ellipsoid

$$U_0 = U(a, f, \omega, GM); \text{ or } U_0 = U(a, J_2, \omega, GM)$$



Then by definition:

$$W_0 \overset{!}{=} U_0$$

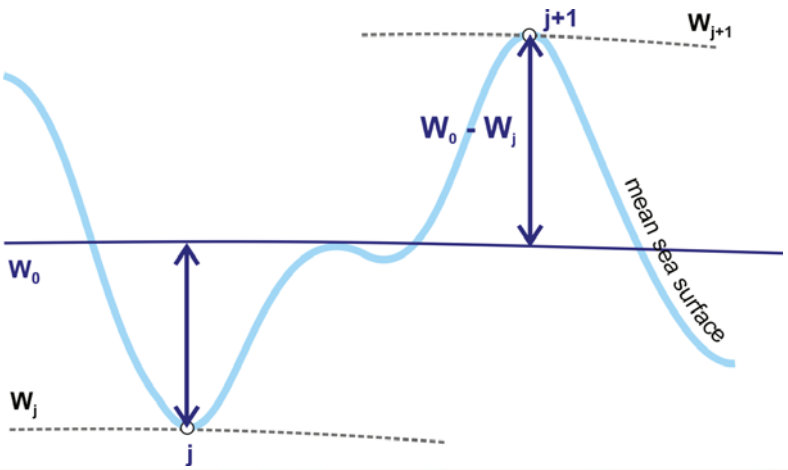
Empirical estimation of W_0

Late 1990s and 2000s:

$$\int_S \Xi^2 ds = \min; \quad \Xi = \frac{W_0 - W_j}{\gamma_j}$$

Ξ : Sea surface topography

- Points *j* with coordinates from satellite altimetry describe the mean sea surface;
- Potential values *W* are derived from a global gravity model



Empirical estimation of W_0

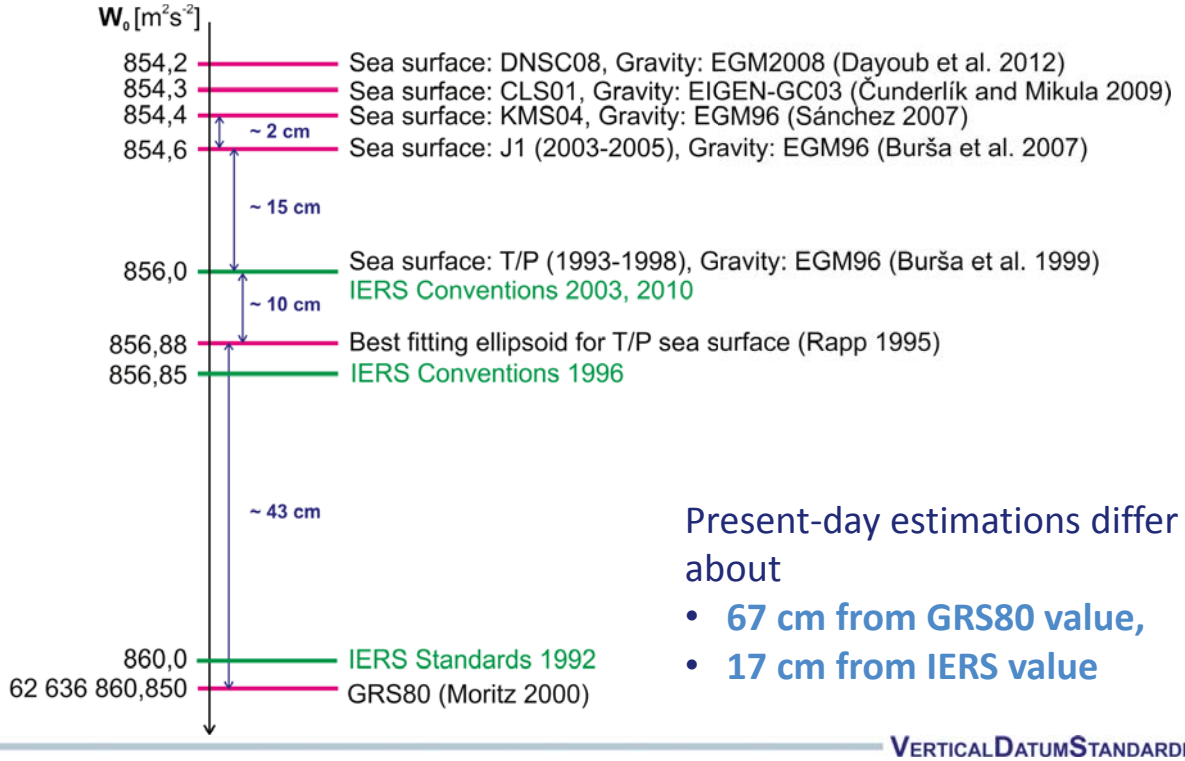
Today: solution of the fixed geodetic boundary value problem:

$$\nabla^2 \delta W(\mathbf{X}) = 0 \qquad \mathbf{X} \in \Omega$$
$$\delta W(\mathbf{X}) \to 0 \qquad \mathbf{X} \to \infty$$
$$\delta g(\mathbf{X}) = g(\mathbf{X}) - \gamma(\mathbf{X}) \qquad \mathbf{X} \in \Sigma$$

Boundary surface Σ known;
Unknown: disturbing potential δW (=W_0-U_0)
Boundary condition: gravity disturbances δg
Regularisation: δW vanishes at infinity

X ↔ sea surface from satellite altimetry, continental surfaces from SMRT
g(**X**) ↔ global gravity model
γ(**X**), U_0 ↔ GRS80

Some examples of W_0 estimates



Present-day estimations differ about

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

Remarks on W_0

- The reference level W_0 for potential differences **can arbitrarily be appointed**. However, to get the worldwide consistency desired within a global vertical reference system, the selected **W_0 value must be realisable** with **high-precision at any time and anywhere** around the world.
- Since W_0 represents only one quantity and it is not sufficient to estimate position and geometry of the equipotential surface it is defining; **the main problem to solve here is not the determination of the W_0 value *per se*, but its realisation**.
- Therefore, it is necessary to estimate it from **real observations** of the Earth's gravity field and surface.
- The **uniqueness**, **reliability** and **repeatability** of the global reference level W_0 (or global geoid) can only be guaranteed by introducing **specific conventions** (like any other reference system!). On the contrary, there will exist as many height systems as W_0 computations.

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.

WG on Vertical Datum Standardization

On going-activities

L. Sánchez (Germany) ⇨ W_0-computation based on fixed-GBVP, analytical solution

R. Čunderlík (Slovakia)
Z. Faskova (Slovakia)
K. Mikula (Slovakia) ⇨ W_0-computation based on fixed-GBVP, Boundary Element Method (BEM), Finite Element Method (FEM) and Finite Volume Method (FVM).

N. Dayoub (Syria)
P. Moore (United Kingdom) ⇨ W_0-computation based on averaging W-values from a GGM on points describing the sea surface (MSS)
W_0-computation based on a reference ellipsoid ($W_0 = U_0$)

Z. Šima (Czech Republic)
V. Vatrt (Czech Republic)
M. Vojtiskova (Czech Republic) ⇨ W_0-computation based on averaging W-values from a GGM on points describing the sea surface (MSS)

J. Huang (Canada)
D. Roman (USA)
Y. Wang (USA)
J. Ågren (Sweden) ⇨ Regional realisation of a global W_0

WG on Vertical Datum Standardization

First results

The different teams computed W_0 using the same input data, but their own methodologies.

Estimates provided by N. Dayoub

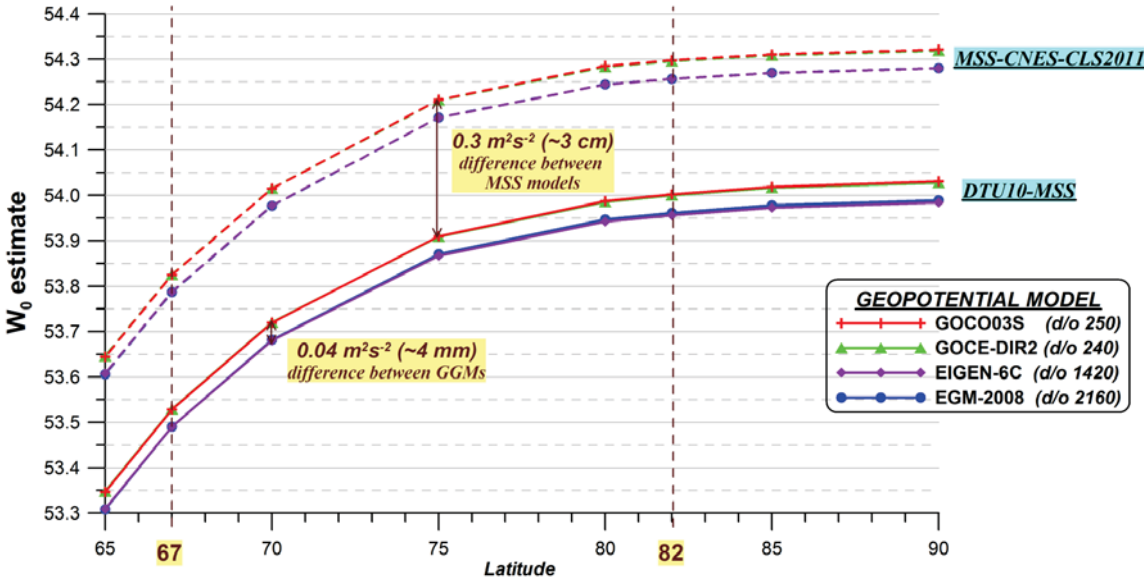
MSS	Domain N/S	GGM	Max degree	$W_0(m^2s^{-2})$		
				1996.0	2001	2005
CLS11	82°/82°	EIGEN6C	n=200	62636854.43		62636854.19
		GOCO03S		62636854.43		62636854.19
	67°/67°	EIGEN6C		62636854.06		62636853.82
		GOCO03S		62636854.06		62636853.82
DTU10	82°/82°	EIGEN6C			62636854.11	62636854.00
		GOCO03S			62636854.11	62636854.00
	67°/67°	EIGEN6C			62636853.75	62636853.64
		GOCO03S			62636853.75	62636853.64

- W_0-dependence on the latitude coverage.
- W_0-dependence on the reference epoch of the mean sea surface model and potential coefficients.

WG on Vertical Datum Standardization

First results

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

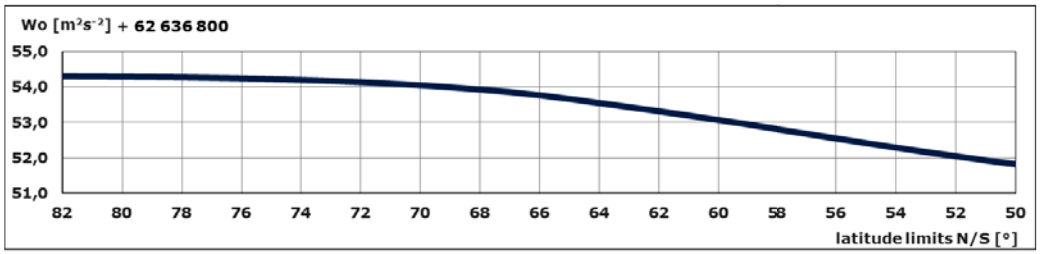


- W_0-dependence on the spectral resolution of the gravity model.

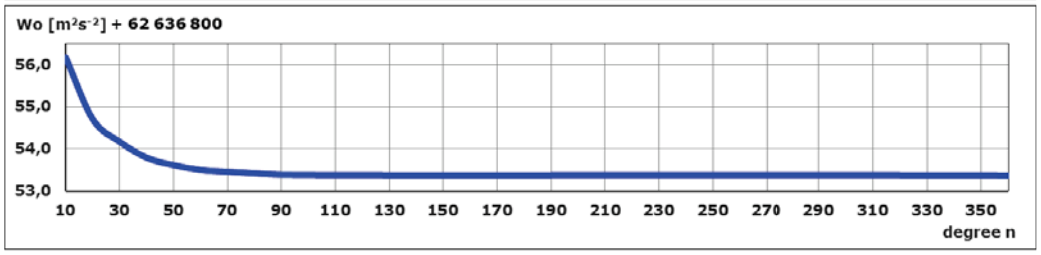
WG on Vertical Datum Standardization

First results

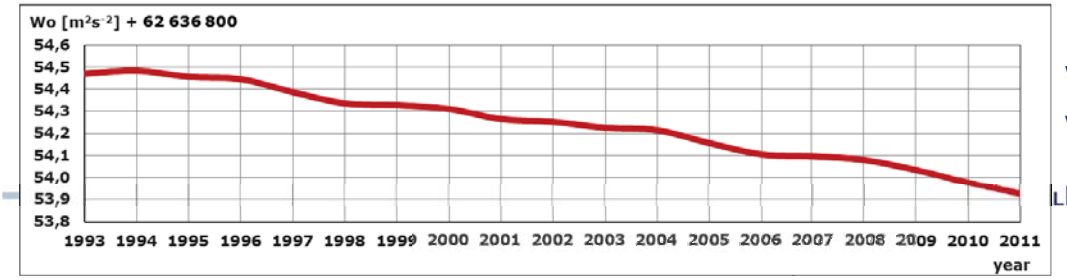
Estimates provided by L. Sánchez



W_0-variation with latitudinal coverage.



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



W_0-variation with time.

Outlook

- All the computations are delivering very close results, 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.

Splinter Meeting @ GGHS 2012: Thursday, Oct. 11, 6:15 pm. Room 8.
To join the group visit http://whs.dgfi.badw.de or send a message to sanchez@dgfi.badw.de.

Vertical Datum Standardisation

Joint Working Group JWG 0.1.1 of

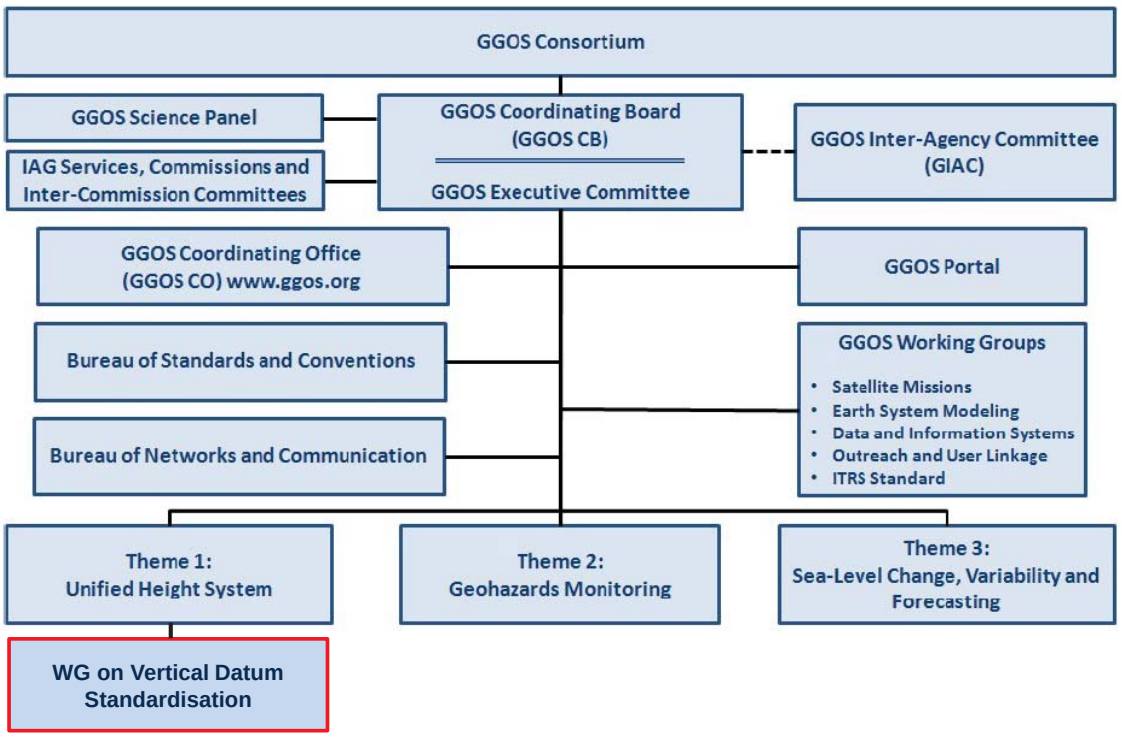
GGOS Theme 1: Unified Global Height System
IAG Commission 1: Reference Frames
IAG Commission 2: Gravity Field
International Gravity Field Service

Splinter Meeting @ GGHS 2012, October 11, 2012

Agenda

- Introduction to the WG
- The global reference level
- Local/regional realisation of the global reference level
- Website

A Unified Height System: a GGOS challenge



Global vertical reference system: definition and realisation

(IAG-ICP1.2: Vertical Reference Frames, Ihde et al. 2007)

Consistent modelling of geometric and physical parameters, i.e.
$h = H^N + \zeta$ ($\approx H + N$) in a global frame with high accuracy ($< 10^{-9}$)

Geometrical Component	Physical Component
Coordinates: **h (t), dh/dt** Definition: **ITRS + Level ellipsoid ($h_0 = 0$)** a. (**a**, J2, ω, GM) **or** b. (**W_0**, J2, ω, GM) Realisation: 1. Related to the **ITRS** (ITRF) 2. Conventional ellipsoid Conventions: IERS Conventions Ellipsoid constants, W_0, U_0 values, reference tide system have to be aligned to the physical conventions!	Coord.: Potential differences **$-\Delta W_P(t) = W_0(t) - W_P(t)$; $d\Delta W_P/dt$** Definition: **W_0= *const.*** (as a convention) Realisation: 1. Selection of a global **W_0** value 2. Determination of the local **$W_{0,j}$** values 3. Connection of **$W_{0,j}$** with **W_0** 4. Geometrical representation of **W_0** and **$W_{0,j}$** (i.e. geoid comp.) 5. Potential differences into physical heights (**H** or **H^N**) **Zero tide system**

GGOS Theme 1: Short-term items

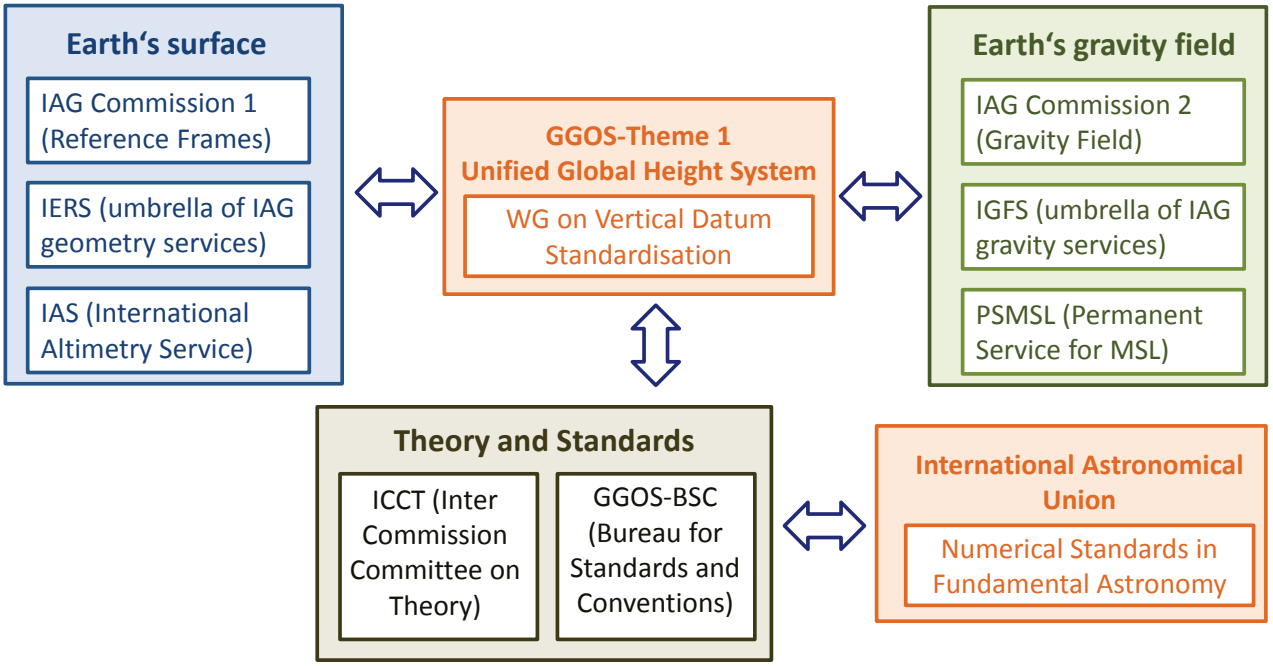
(IAG Geodesist Handbook 2012)

01: Refinement of standards and conventions for the definition and realisation of a Global Unified Height System: identification of missing or out-dated standards and conventions necessary for the global height system realisation.

02: Divulgation and integration of the global height system standards and conventions within the IAG components (Commissions, Services, GGOS): disagreements with the existing standards and conventions of other IAG components shall be analysed and the corresponding updates (modifications) shall be implemented in order to achieve a homogenous set of common numerical standards, models, and procedures.

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.

Interaction with other IAG/GGOS components



About W_0 estimations

One year ago:

- Three very close W_0 estimations (~0,2 m^2s^{-2}): Čunderlik et al., Dayoub et al., Sánchez et al. (computations started in 2005)
- One W_0 estimation far away (~2 m^2s^{-2}): Burša et al. (computations from 1999 thru 2011 produce the same value)

Today:

- Burša et al. estimation came close to the others.
- IERS includes the "old" Burša value, but this value has not been formally adopted or recommended by the IAG (nor IUGG).

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?

About W_0 estimations

If "a best present estimate" shall be recommended:

- should it be an agreement between (signed by) the four groups? (Čunderlik et al., Dayoub et al., Sánchez et al., Burša et al.)
- or should each group make an individual recommendation? If yes, who shall make the decision about the "best estimation"?

How shall the "agreed upon" recommendation be supported?

- a common position paper describing models and methods applied in the individual estimations?
- or individual papers (per group) and then a short common summary?

What about a WG (common) contribution for the GGHS2012 Proceedings?

About W_0 estimations

Planned activities by the individual groups to refine their estimations: (still open questions)

- 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.

Local/regional realisation of the global reference level

Possible strategy: Combination of geometric and physical heights?

Ellipsoidal heights:

- GNSS (mainly on land);
- Satellite altimetry (on oceans);
- Scanning geodetic techniques (SRTM, InSar, Lidar, etc.)
- …

Physical heights:

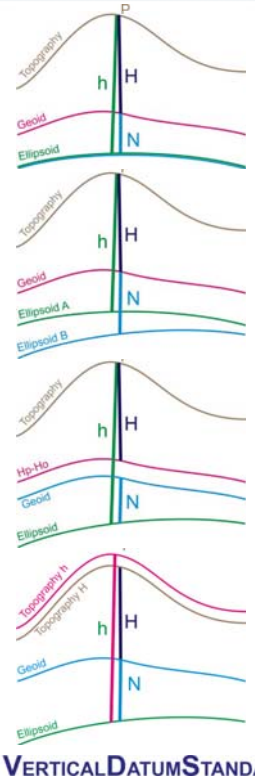
- Spirit levelling + gravity reductions
- Oceanic levelling (steric and geostrophic)
- …

(Quasi)Geoid models:

- Global gravity models + terrestrial (airborne, marine) gravity data.

Combination of geometric and physical heights

- Usage of different ellipsoid parameters
- Heights (h, H, N) in different tide systems
- Mixture of orthometric hypothesis (heights and geoids)
- Omission of levelling error accumulation
- Different reference epochs (unknown dH/dt)
- Different reductions (Earth-, ocean-, atmospheric tides, ocean and atmospheric loading, post-glacial rebound, etc.)
- Not appropriate error propagation analysis in the combination of satellite and terrestrial gravity data.



Combination of geometric and physical heights

- Ellipsoidal heights follow the IERS Conventions. Are there similar conventions for physical heights and geoid modelling?
- Taking into account (and advantage of) the experience of colleagues working on
  - regional vertical datum unification,
  - evaluation of global gravity models,
  - modernisation of height systems

  can our WG try to outline the basic standards to be followed by the three coordinates (h, H, N) to guarantee a consistent combination?
- How do you want to contribute to this topic?

http://whs.dgfi.badw.de

At present:

- Terms of reference of the WG (objectives, plan of activities members)
- ICP1.2 Documents (Conventions, presentations, reports, meeting summaries, etc.)

What else?

- Terms of reference for GGOS Theme 1? (They are missing in the GGOS web page).
- A list of references with recent “vertical datum”-related publications?
- Symposium presentations of the WG members?
- ….?