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. Mákinen (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 $L_0$ 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 (Čunderlík 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 Čunderlík et al., Dayoub et al., Sánchez et al. were very close to each other (largest discrepancy ~0.2 m$^2$s$^{-2}$); while the estimation of Burša et al. was a little far away (about ~2 m$^2$s$^{-2}$). 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$^2$s$^{-2}$) 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 $L_0$ constant) presents a discrepancy of about ~2 m$^2$s$^{-2}$ 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., Čunderlík 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. **Various**

- 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”*
  

  *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., Šíma Z., Vatrt V., Vojtišková 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., Vaniček 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 K.

- Selected publications related with the Wo estimation:


- Annexes to this meeting summary:
  
  *Report on the activities of the working group "Vertical Datum Standardisation"


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

Desired
Disturbing potential in combination with a reference ellipsoid

In the future
Global gravity field models in combination with ITRS/ITRF coordinates
Comparison of clock frequencies of high-precision

Today
\[ C(g, dn) = W_0 - W_0 = \int g \delta n \approx \sum g \, dn \]

Desired
\[ C(U_0, T) = -(U_0 - W_0) + \bar{f}(\phi)h - T(\phi, \lambda, h) \]

In the future
\[ C(\mathbf{C}_{mn}, \mathbf{S}_{mn}) = W_0 - [V(r, \theta, \phi) + Z(r, \theta)] \]

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

Reference level depending on input data?

How can we guarantee
\[ C(g, dn) \approx C(U_0, T) \approx C(\mathbf{C}_{mn}, \mathbf{S}_{mn}) \approx C(f) \]

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 \((W_0\text{ or geoid})\) 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)

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

\[ W_0 = U_0 \]

Late 1990s and 2000s:

\[ \sum s^2 = \min; \quad \Xi = \frac{W_0 - W_j}{\gamma_j} \]

- 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:

\[ \nabla^2 \delta W(X) = 0 \quad X \in \Omega \]
\[ \delta W(X) \to 0 \quad X \to \infty \]
\[ \delta g(X) = g(X) - \gamma(X) \quad X \in \Sigma \]

Boundary surface $\Sigma$ known;
Unknown: disturbing potential $\delta W = W_0 - U_0$
Boundary condition: gravity disturbances $\delta g$
Regularisation: $\delta W$ vanishes at infinity

$X \leftrightarrow$ sea surface from satellite altimetry, continental surfaces from SMRT
g(X) \leftrightarrow$ global gravity model
$\gamma(X), U_0 \leftrightarrow$ GRS80

Some examples of $W_0$ estimates

<table>
<thead>
<tr>
<th>$W_0$ [m$^2$s$^{-2}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>854.2</td>
</tr>
<tr>
<td>854.3</td>
</tr>
<tr>
<td>854.4</td>
</tr>
<tr>
<td>854.6</td>
</tr>
<tr>
<td>~ 2 cm</td>
</tr>
<tr>
<td>~ 15 cm</td>
</tr>
<tr>
<td>856.0</td>
</tr>
<tr>
<td>~ 10 cm</td>
</tr>
<tr>
<td>856.88</td>
</tr>
<tr>
<td>856.85</td>
</tr>
<tr>
<td>~ 43 cm</td>
</tr>
<tr>
<td>860.0</td>
</tr>
<tr>
<td>52 636 860,850</td>
</tr>
</tbody>
</table>

Sea surface: DNDC08, Gravity: EGM2008 (Dayoub et al. 2012)
Sea surface: CLS01, Gravity: EIGEN-GC03 (Cunderlik and Mikula 2009)
Sea surface: KMS04, Gravity: EGM96 (Sánchez 2007)
Sea surface: J1 (2003-2005), Gravity: EGM96 (Burša et al. 2007)
IERS Conventions 2003, 2010
Best fitting ellipsoid for T/P sea surface (Rapp 1995)
IERS Conventions 1996
IERS Standards 1992
GRS80 (Moritz 2000)

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)  
  - $W_0$-computation based on fixed-GBVP, Boundary Element Method (BEM), Finite Element Method (FEM) and Finite Volume Method (FVM).

- Z. Faskova (Slovakia)  
  - $W_0$-computation based on averaging $W$-values from a GGM on points describing the sea surface (MSS)

- K. Mikula (Slovakia)  
  - $W_0$-computation based on a reference ellipsoid ($W_0 = U_0$)

- N. Dayoub (Syria)  
  - $W_0$-computation based on averaging $W$-values from a GGM on points describing the sea surface (MSS)

- P. Moore (United Kingdom)  
  - Regional realisation of a global $W_0$

- Z. Šima (Czech Republic)  
  - Regional realisation of a global $W_0$

- V. Vatrt (Czech Republic)  
  - Regional realisation of a global $W_0$

- M. Vojtiskova (Czech Republic)  

- J. Huang (Canada)  

- D. Roman (USA)  

- Y. Wang (USA)  

- J. Ågren (Sweden)  

---

**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**

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

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

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

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

$W_0$-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 m²s⁻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

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

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})

<table>
<thead>
<tr>
<th>Geometrical Component</th>
<th>Physical Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinates: ( h(t), dh/dt )</td>
<td>Coord.: Potential differences (-\Delta W_p(t) = W_0(t) - W_p(t); d\Delta W_p/dt)</td>
</tr>
<tr>
<td>Definition: ( \text{ITRS + Level ellipsoid (} h_0 = 0) )</td>
<td>Definition: ( W_0 = \text{const.} ) (as a convention)</td>
</tr>
<tr>
<td>( a, J_2, \omega, \text{GM} ) ( a ) ( W_0, J_2, \omega, \text{GM} ) ( b )</td>
<td>Realisation:</td>
</tr>
<tr>
<td>Realisation: ( 1. ) Related to the ( \text{ITRS (ITRF)} ) ( 1. ) Selection of a global ( W_0 ) value ( 2. ) Conventional ellipsoid ( 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 ))</td>
<td></td>
</tr>
<tr>
<td>Conventions: ( \text{IERS Conventions} )</td>
<td>Zero tide system</td>
</tr>
<tr>
<td>Ellipsoid constants, ( W_0, U_0 ) values, reference tide system have to be aligned to the physical conventions!</td>
<td></td>
</tr>
</tbody>
</table>
Interaction with other IAG/GGOS components

**Earth’s surface**
- IAG Commission 1 (Reference Frames)
- IERS (umbrella of IAG geometry services)
- IAS (International Altimetry Service)

**GGOS-Theme 1**
- Unified Global Height System
- WG on Vertical Datum Standardisation

**Earth’s gravity field**
- IAG Commission 2 (Gravity Field)
- IGFS (umbrella of IAG gravity services)
- PSMSL (Permanent Service for MSL)

**Theory and Standards**
- ICCT (Inter Commission Committee on Theory)
- GGOS-BSC (Bureau for Standards and Conventions)

**International Astronomical Union**
- Numerical Standards in Fundamental Astronomy

---

**About \( W_0 \) estimations**

**One year ago:**
- Three very close \( W_0 \) estimations (~0.2 m\(^2\)s\(^{-2}\)): Čunderlik et al., Dayoub et al., Sánchez et al. (computations started in 2005)
- One \( W_0 \) estimation far away (~2 m\(^2\)s\(^{-2}\)): 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\(^2\)s\(^{-2}\) 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?

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?

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?
- ....?

http://whs.dgfi.badw.de