International Association of Geodesy
Commission 1 *Reference Frames,* Commission 2 *Gravity Field*
ICP 1.2 *Vertical Reference Frames*

IAG Inter-Commission Project (ICP) 1.2 *Vertical Reference Frames*
Splinter Meeting
Minutes

01 September, 2009

IAG Scientific Meeting 2009

30 August – 04 September 2009
Buenos Aires
Argentina

Participants of the meeting: Matt Amos, David Avalos, Robert Čunderlík, Paul Denys, Theresa Diehl, Silvio R.C.de Freitas, Petr Holota, Johannes Ihde, Karoline Paes Jamur, Gary Johnston, Jan Krynski, Mikael Lilje, Adam Lyszkowicz, Jaakko Mäkinen, Urs Marti, Pavel Novák, Rogers Ademir Drunn Pereira, Markku Poutanen, Daniel Roman, Robert Sarib, Michael Sideris, Zdislav Šíma, Janusz Sledzinski, Dru Smith, Dag Solheim, Robert Tenzer, Viliam Vatrt, Olav Vestol, Marie Vojtiskova, Bill Kearsly
(See Annex 1 and Annex 2)

Begin: Sept. 01, 2009, 6:00 p.m.; **End:** Sept. 01, 2008, 7:30 p.m.

Objective of the meeting: Agreement about a Call for Participation (CfP) for the realization of a WHS.

Agenda

- **Introduction**
- **Contributions of participants**
- **Discussion of the draft CfP**
- **Decision on contents and time table and responsibilities of CfP**

Introduction

At the last Splinter Meeting at the International Symposium on Gravity, Geoid & Earth Observation 2008, Chania, Greece the following action items were agreed:

- Preparation of a Workshop in Spring 2008 (until Dec. 15, 2008)
- The ICP1.2 members were asked to propose a meeting place and date. BKG offered to host the meeting in April 2008 one week before the EGU GA in Vienna.
- The ICP1.2 members were asked to propose discussion items for the agenda

- Development of the concept for a pilot project (J. Ihde and interested members of ICP1.2, until end of January 2009)
- Discussion of the continuation of Work at the IAG GA 2009.

Discussion of the draft CfP
Johannes Ihde introduced by a ppt presentation (see Annex 3) a draft proposal of a pilot project for the Realization of a World Height System (Annex 4). The draft pilot project description was distributed before the splinter meeting in Buenos Aires and changed in details following recommendations of ICP members.

The pilot project (WHS-PP) could start with a case study consisting of the following elements and principles:

(1) The numerical standards of IERS conventions 2003 or its update
(2) The global gravity model EGM2008 and a satellite only GGM (tbd) with continental and national densifications
(3) Fixing a conventional W_0 and monitor the relationship to the potential of the Earth gravity field closely coinciding with the mean sea surface
(4) GNSS/levelling stations with coordinate time series in the ITRFxx linked to IGS TIGA stations and geo-potential numbers in relationship to the RHS at defined epochs
(5) An Information system (registry) providing relevant data and information

Partners for the WHS-PP are inside the IAG the IGFS for GGM, absolute and super conducting gravity meter measurements, IGS for TIGA, SC2.4 for continental and regional densification of a GGM and GLOSS for PSMSL and a global sea surface topography model.

Summary of the discussion of the draft CfP

The participants agreed that the WHS realization is necessary. The introduction of a pilot project for the realization of a WHS was considered as a useful step.

The discussion was mainly related to the WHS-PP Work Items (WI) of the CfP:

1. ***Analysis centres for investigations of the representation accuracy of EGM2008 and for the evaluation and selection of a satellite only GGM***

   This item was controversially discussed. Several participants don't see:
   - The necessity to investigate the representation accuracy of EGM08 since a publication of BGI International Geoid Service Newton's Bulletin: External Quality Evaluation Reports of EGM08. Issue no 4, April 2009 is already available.
   - The necessity to select a satellite only GGM e.g. GOCE, if GOCE models not yet available.

   It is proposed to reformulate this Work Item: ***Investigations of the representation accuracy of EGM2008 and for the determination and selection of a satellite only GGM***

2. ***Analysis centers for the determination and monitoring of the relationship of W_0 to the potential of the Earth gravity field closely coinciding with the mean***

sea surface and for the determination of improved mean Earth Ellipsoid (mEe) parameters

Colleagues from the Burša group announced a contribution for the case that this Work Item will be called.

3. ***Regional processing centers and global combination centers for GNSS/levelling stations with coordinate time series in the respectively valid ITRF linked to IGS TIGA stations and geo-potential numbers referred to the RHS at defined epochs***

4. ***Analysis centers for combining of absolute and superconducting gravity measurement for monitoring of vertical movements***

   After a discussion it was agreed to leave this item in the CfP.

5. ***Investigations on the accuracy for computing point values Wp of the gravity potential by means of high resolution gravity field models and regional densifications of gravity data***

   Several speakers remarked that the EGM08 should be the basis for the WHS without regional gravity densifications. The gravity densifications would disturb the homogeneity of the gravity field presentation by the EGM08.

6. ***Development of an information system (registry) providing relevant data and information***

   The necessity of this WI was accepted.

It is assumed that the results of the TIGA PP are available.

In the meantime Johannes Ihde contacted members of the ICP1.2 to draft the CfP. The following responsibilities were agreed (in brackets not yet contacted or agreed):

WI01: Johannes Ihde, Urs Marti, (GFZ Potsdam, Dru Smith)
WI02: Laura Sánchez
WI03: Tilo Schöne, (Laura Sánchez, Gery Johnston)
WI04: Herbert Wilmes
WI05: Urs Marti
WI06: Gunter Liebsch

Relations to TIGA PP: Tilo Schöne

Schedule

Circulation of the first draft PP	11/2009
WHS PP Call for Participation	02/2010
Proposals submitted in response to the Call for Participation	04/2010
Selection of the proposals	06/2010
Survey of WHS PP results	05/2011
Recommendations for implementation	07/2011

Post considerations and activities:

In the mean time discussions with several colleagues have shown that there is a need for special consideration of countries with a weak geodetic infrastructure. At present ICP1.2 is focussed to scientific developments for a high precise WHS in context with the IAG initiative GGOS. More than 100 countries worldwide have no or a weak geodetic infrastructure. It seems to be useful to have one WI with a special focus to such regions of the world:

7. Operative Determination of physical WHS heights in regions with a weak geodetic infrastructure

Responsible for WI07: Johannes Ihde, (Mikae Lilje, Bill Kearsley)

Keeper of the Minutes: Johannes Ihde

Annexes:

1. Participants of the ICP1.2 Meeting
2. Participants of the ICP1.2 Meeting Chania
3. Introductory ppt presentation
4. Draft Pilot Project for the Realization of a World Height System (WHS)

page 1 / IAG-ICP 1.2 Meeting

Buenos Aires, Sept. 1, 2009

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page 2

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Vertical Reference Frames
- IAG Inter-Commission Project 1.2

(Joint with Commission 2 and IGFS)

ICP1.2 Splinter Meeting
September 01, 2009

IAG Scientific Assembly 2009
"Geodesy for Planet Earth“
Buenos Aires/Argentina; August 31 -- September 4, 2009

Objective

Agreement about a call for participation for Realization of a WHS

Agenda

- Introduction (JI)
- Contributions of participants
- Discussion of the draft CfP
- Decision about contents and time table of CfP
- Others:
  - List of participants
  - Keeper of the minutes
  - Resp. of the CfP items

ICP1.2 history

- Formation 2003 in Sapporo/Japan (IUGG GA)
- First Working Group Meeting 2004 in Porto/Portugal (GGSM)
- Second Working Group Meeting 2005 Cairns/Australia (IAG GA)
- Workshop April 2006 in Prague/Czech Republic
- WG Meeting Aug. 2006 in Istanbul/Turkey (1st IGFS Symposium)
- Final discussion on IUGG GA, July 2007 in Perugia/Italy
- Splinter Meeting at International Symposium on Gravity, Geoid & Earth Observation 2008, Chania, Greece - Minutes
- GLOSS Workshop on Precision Observations of Vertical Land Motion, May 11-12, 2009, Paris – Presentation "Realization of a World Height System and its Relationship to GLOSS" (TIGA_PP)

Objectives in the Period 2007 - 2011

- **Continue the open topics of the period 2003 - 2007**
- **Further development of the CVRS conventions**
- **Preparation of a decision about numerical standards in cooperation with International Astronomical Union (IAU) and international hydrological associations.**
- **Initiate of a pilot project for a WHS realization (WHS-PP)**

Program of Activities

- **Study of information on regional vertical systems and their relations to a WHS for practical applications;**
- **Study of combination procedures of height data sets from different techniques;**
- **Development of the basic relationships between WHS and IVRS conventions, parameters, realization, models**
- **Unification of regional (continental) height systems**
- **Preparation of a pilot project for the realization of a WHS.**

The project continuation shall be realized in cooperation with other organizations, especially the

- International Association of Hydrological Sciences (IAHS)
- International Association for the Physical Sciences of the Oceans (IAPSO)
- **Global Sea Level Observing System (GLOSS)**
- **International Hydrographic Organisation (IHO)**
- International Federation of Surveyors (FIG) and
- **Inter-service Geospatial Working Group (IGeoWG) of NATO**
- **UNESCO**

Splinter Meeting at International Symposium on Gravity, Geoid & Earth Observation 2008, Chania, Greece – Minutes, Action Items

- Preparation of a Workshop in Spring 2008 (until Dec. 15, 2008)
  - The ICP1.2 members were asked to propose a meeting place and date. BKG offer to host the meeting in April 2008 one week before the EGU GA in Vienna.
  - The ICP1.2 members were asked to propose discussion items for the agenda.
- Development of the concept for a pilot project (J. Ihde and interested members of ICP1.2, until end of January 2009)
- Discussion of the continuation of Work at the IAG GA 2009

Realization Concept of a WHS

The general case for realization of a WHS and unification of continental VRS is the combination of GNSS and if possible of GNSS/levelling with a global gravity model (GGM) which is named as the geodetic boundary value problem (GBVP) approach. This approach is the combination of different components:

- **A global permanent GNSS network of stations connected with levelling networks, optionally supplemented by permanent (superconducting) and/or periodical (absolute) gravity observations at selected stations**
- **A global gravity model (GGM) with continental and regional densifications.**

Mandatory elements for a WHS

1. Numerical Standards (e.g. mean Earth ellipsoid – mEe, ...)
2. Global gravity model (GGM) with continental and/or national densifications
3. Monitored relationship of W_0 to the potential of the Earth gravity field closely coinciding to the mean sea surface

For existing local and regional height systems – RHS (chart datums and levelling networks)

4. GNSS/levelling stations with coordinate time series in the ITRFxx and geo-potential numbers in relationship to the RHS at a defined epochs

Optional elements for a WHS:

5. GNSS stations, which monitors vertical movements in ITRFxx
6. Tide gauge station observations for selected stations (5)
7. Absolute and superconducting gravity measurement at selected stations (5)
8. Information system (registry) providing relevant data and information

WHS Pilot Project

The pilot project (WHS-PP) could start with a case study consisting with the following conditions and elements:

1. **The numerical standards of IERS conventions 2003**
2. **The global gravity model EGM2008 and a satellite only GGM (tbd) with continental and national densifications**
3. **Monitored relationship of W_0 to the potential of the Earth gravity field closely coinciding to the mean sea surface**

4. GNSS/levelling stations with coordinate time series in the ITRFxx linked to IGS TIGA stations and geo-potential numbers in relationship to the RHS at a defined epochs
5. GNSS/tide gauge stations of the IGS TIGA PP, which monitor vertical movements in ITRFxx
6. Tide gauge observations linked to IGS TIGA stations
7. Absolute and superconducting gravity measurement at selected GGP stations linked by GNSS to IGS TIGA stations
8. Information system (registry) providing relevant data and information

Call for participation for the following WHS-PP Work Items:

1. Analysis centres for investigations of the representation accuracy of EGM2008 and for the determination and selection of a satellite only GGM
2. Analysis centres for the determination and monitoring of the relationship of W_0 to the potential of the Earth gravity field closely coinciding to the mean sea surface and for the determination of a improved mEe parameters
3. Regional processing centres for GNSS/levelling stations with coordinate time series in the ITRFxx linked to IGS TIGA stations and geo-potential numbers in relationship to the RHS at a defined epochs

4. Analysis centres for combining of absolute and superconducting gravity measurement for monitoring of vertical movements
5. Investigations on the accuracy for computing point values Wp of the gravity potential by a high resolution gravity field model and regional densification of gravity data
6. Development of an information system (registry) providing relevant data and information

It is assumed that the results of the TIGA PP are available.

Schedule

- Circulation of the first draft PP 10/2009
- WHS PP Call for participation 01/2010
- Proposals submitted in response to the call for participation 03/2010
- Selection of the proposals 05/2010
- Survey of WHS PP results 05/2011
- Recommendations for implementation 07/2011

IAG Inter-Commission Project 1.2
Vertical Reference Frames

Draft
Pilot Project
Realization of a World Height System (WHS)

1. The ICP1.2 *Vertical Reference Frames*

The results of the work of the Inter-commission Project 1.2 in the first term 2003 – 2007 are documented in **Conventions for the Definition and Realization of a Conventional Vertical Reference System (CVRS)**. In the CVRS conventions a general concept for the definition and realization of a unified, global vertical reference system is described. The CVRS conventions are aligned to the IERS 2003 Conventions. The definition and realization of a World Height System (WHS) is a fundamental requirement of GGOS. In the same way as the ITRS/ITRF provides a high precision geometrical reference frame, the WHS shall provide the corresponding high precision physical reference frame for studying the system Earth.

Objectives in the Period 2007 - 2011

- Continue the open topics of the period 2003 - 2007
- Further development of the CVRS conventions
- Preparation of a decision on numerical standards in cooperation with the International Astronomical Union (IAU) and international hydrological associations.
- Initiation of a pilot project for a WHS realization (WHS-PP)

Program of Activities

- Study of information on regional vertical systems and their relations to a WHS for practical applications;
- Study of combination procedures of height data sets from different techniques;
- Development of the basic relationships between WHS and ITRS conventions, parameters, realization, and models
- Unification of regional (continental) height systems
- Preparation of a pilot project for the realization of a WHS.

The project continuation shall be realized in cooperation with other organizations, especially the International Association of Hydrological Sciences (IAHS), the International Association for the Physical Sciences of the Oceans (IAPSO), UNESCO Global Sea Level Observing System (GLOSS), the International Hydrographic Organisation (IHO), the International Federation of Surveyors (FIG), and the Inter-service Geospatial Working Group (IGeoWG) of NATO.

2. The Realization Concept of a WHS

The realization of a WHS can be achieved mainly through the combination of different products of IAG services. The general case for realization of a WHS and unification of continental VRS is the combination of GNSS and if possible of GNSS/levelling with a global gravity model (GGM) which is named as the geodetic boundary value problem (GBVP) approach. This approach requires the following components:

- A global permanent GNSS network of stations connected with levelling networks, optionally supplemented by permanent (superconducting) and/or periodical (absolute) gravity observations at selected stations
- A global gravity model (GGM) with continental and regional densifications.

As result of this approach we have available physical heights or geopotential numbers related to a geoid/quasigeoid $\boldsymbol{T_{p\ RRT}}$ which is related to a conventional zero level of the potential of the Earth gravity field W_{0C}.

The WHS can be realized for two classes of points with two different procedures:
- GNSS points: $\boldsymbol{c_P = W_{0C} - W_P}$ ***and*** $\boldsymbol{W_p = U_{p\ GPS} + T_{p\ RRT}}$ and
- points of levelling networks k: $\boldsymbol{c_P = c_{P\,k} + W_{0C} - W_{0k}}$. By this, $\boldsymbol{c_{P\,k}}$ will be transformed from the regional level $\boldsymbol{W_{0k}}$ to the conventional global level $\boldsymbol{W_{0C}}$. The difference $\boldsymbol{W_{0C} - W_{0k}}$ can be determined by GNSS/levelling in selected co-location points by $\boldsymbol{W_{0C} - T_p - U_{p\ GPS} - c_{P\,k}}$.

An alternative approach which can be used for the unification of vertical reference frames is based on the combination of tide gauge observations with a global sea surface topography model. It is necessary that the tide gauge stations are linked to the regional levelling network and to the geometrical reference system ITRS/ITRF. (This approach will not further be considered?).

In general, the realization und unification is a combination of the different elements based on a set of consistent conventional numerical standards. The accuracy of WHS realization depends in the first order on the resolution of the gravity field model and the appropriate regional densification with gravity data. A service providing all relevant information would be useful.

Mandatory elements for a WHS:

(1) Numerical Standards (mean Earth ellipsoid – mEe, ...)
(2) Global gravity model (GGM) with continental and/or national densifications

For existing local and regional height systems – RHS (chart datums and levelling networks)

(3) GNSS/levelling stations with coordinate time series in the respectively valid ITRF and geo-potential numbers in relationship to the RHS at a defined epoch with derived Relationship (transformation parameters) between the global WHS and the regional RHS

Optional elements for a WHS:

(4) Monitored relationship of W_0 to the potential of the Earth gravity field closely coinciding with the mean sea surface
(5) GNSS/tide gauge stations to monitor vertical movements in the respectively valid ITRF
(6) Tide gauge station observations for selected stations (5)
(7) Absolute and superconducting gravity measurement at selected stations (5)
(8) Information system (registry) providing relevant meta data.

3. WHS Pilot Project

The pilot project (WHS-PP) will start with a case study consisting of the following elements:

(1) The numerical standards of IERS conventions 2003
(2) The global gravity model EGM2008 and a satellite only GGM (tbd) with continental and national densifications

(3) Monitored relationship of W_0 to the potential of the Earth gravity field closely coinciding with the mean sea surface
(4) GNSS/levelling stations with coordinate time series in the respectively valid ITRF linked to IGS TIGA stations and geo-potential numbers referred to the RHS at defined epochs
(5) GNSS/tide gauge stations of the IGS TIGA PP to identify vertical movements of the tide gauges with respect to the ITRF
(6) Tide gauge observations linked to IGS TIGA stations to separate sea level changes from vertical crustal movements at the tide gauge stations and derived mean sea level at the given epoch of the sea surface topography model
(7) Absolute and superconducting gravity measurement at selected GGP stations linked by GNSS to IGS TIGA stations
(8) Information system (registry) providing relevant data and meta data.

Partners for the WHS-PP are inside the IAG: the IGFS for GGM, absolute and super conducting gravity meter measurements, IGS for TIGA, SC2.4 for continental and regional densification of a GGM and GLOSS for PSMSL for tide gauge measurements, and the IAS (International Altimetry Service) for a global sea surface topography model.

Call for participation for the following WHS-PP Work Items:

1. Analysis centers for investigations of the representation accuracy of EGM2008 and for the evaluation and selection of a satellite only GGM
2. Analysis centers for the determination and monitoring of the relationship of W_0 to the potential of the Earth gravity field closely coinciding with the mean sea surface and for the determination of an improved mEe parameter
3. Regional processing centers and global combination centers for GNSS/levelling stations with coordinate time series in the respectively valid ITRF linked to IGS TIGA stations and geo-potential numbers referred to the RHS at defined epoch
4. Analysis centers for combining absolute and superconducting gravity measurement for monitoring of vertical movements
5. Investigations on the accuracy for computing point values W_p of the gravity potential by means of high resolution gravity field models and regional densifications of gravity data
6. Development of an information system (registry) providing relevant data and meta data

It is assumed that the results of the TIGA PP are available.

Schedule

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Proposals submitted in response to the Call for Participation	04/2010
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Recommendations for implementation	07/2011

Johannes Ihde
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