Vertical Reference Framework Update on IAG 1.2

Not much seems to have happened with respect to this project since TWLWG1. I attach a report from the Chair, Johannes Ihde to the IAG Scientific Meeting. Johannes informed members that he was organising a side meeting on this topic at the "GEODESY FOR PLANET EARTH" meeting in Buenos Aires in September 2009 but I have not seen any outcome from this meeting but also attach a draft Pilot Project prepared by Johannes for discussion at this meeting.

Inter-Commission Project 1.2: Vertical Reference Frames

Chair: Johannes Ihde (Germany)

1. The ICP1.2 Vertical Reference Frames in the Period 2007 - 2011

The IAG Inter-Commission Project 1.2 studied during the period 2003 – 2007 the possibilities of the definition and realization of a global vertical reference system (GVRS) based on the classical and modern observations and a consistent modeling of both, geometric and gravimetric parameters.

The results of the work of the Inter-commission Project 1.2 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. Parts of the IERS 2003 conventions are the basis for the CVRS conventions.

Open topics are concepts for the
- Establishment of an information system describing the various regional vertical reference frames and their relation to a GVRS,
- Determination of transformation parameters between regional vertical reference frames and the unified global height system as well as
- Relationship between a GVRS and the International Terrestrial Reference System.

Objectives in the period 2007 - 2011

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

Program of Activities

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

2. The Realization Concept

The realization of an IVRS is a typical item of the IAG project GGOS, mainly as a 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 is the combination of different components:
- A global permanent GNSS network of stations connected with levelling networks, optionally supplemented by permanent (SG) and/or periodical (AG) gravity observations at selected stations
- A global gravity model (GGM) with continental and regional densifications using the remove restore technique.

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}. W_{0C} is a parameter of the mean Earth ellipsoid which shall used for all realization procedures of the WHS.

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: $c_P = c_{P\,k} + W_{0C} - W_{0k}$. By this, $c_{P\,k}$ will be transformed from the regional level W_{0k} to the conventional global level W_{0C}. The Difference $W_{0C} - W_{0k}$ can be determined by GNSS/levelling in selected co-location points by $W_{0C} - T_p - U_{p\,GPS} - c_{P\,k}$.

A further approach which can be used for the unification of vertical reference frames bases 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.

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 from the resolution of the gravity model. A service providing all relevant information would be useful.

3. WHS Pilot Project

The pilot project (WHS-PP) could start with a case study of combination of available elements:

(1) The global gravity model EGM07 with continental and national densifications
(2) For GNSS the IGS TIGA-PP, which monitors vertical movements of globally distributed tide gauge stations
(3) Continental and national levelling networks linked to IGS TIGA stations
(4) The tide gauge stations observations linked to IGS TIGA stations which are a product of the PSMSL
(5) Absolute and super conducting gravity meter measurement at selected IGS TIGA stations
(6) A global sea surface topography model
(7) The numerical standards of IERS conventions 2003

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 desification of a GGM and GLOSS for PSMSL and a global sea surface topography model.

4. Proposed continuation

The IAG has to clarify inconsistencies in the numerical parameters for integrated geodetic applications. Conventions for the definition and realization of the parameters of the MSSL have also to be agreed.

Proposed items for continuation:

- Discussion of the results of ICP1.2 (GGOS action)
- Initiation of a pilot project for an IVRS realization on the basis of the IGS TIGA-PP, GGP and IGFS for AG and a CGGM (call for participation as an IGFS action)
- Further development of the CVRS conventions
- Decision about numerical standards as task of GGOS in cooperation with International Astronomical Union (IAU) and international hydrological and oceanographic organisations.

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), 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.

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 realization of an IVRS is a typical item of the IAG initiative GGOS

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), the International Association for the Physical Sciences of the Oceans (IAPSO), 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 WHS can be realized mainly as a 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 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.

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 bases 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. 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 model and appropriate regional densification of gravity data. A service providing all relevant information would be useful.

Mandatory elements for a WHS:

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

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

(10) 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:

(11) Monitored relationship of W_0 to the potential of the Earth gravity field closely coinciding to the mean sea surface
(12) GNSS/tide gauge stations, which monitors vertical movements in ITRFxx
(13) Tide gauge station observations for selected stations (5)
(14) Absolute and superconducting gravity measurement at selected stations (5)
(15) Information system (registry) providing relevant data and information

3. WHS Pilot Project

The pilot project (WHS-PP) could start with a case study consisting with 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 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

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.

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

Johannes Ihde
Chairman