Consideration of a Global Vertical Reference System (GVRS) in the IERS Conventions

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Vertical Reference Frames

IERS Workshop on Convention
Sevres
September 20-21, 2007

IAG ICP1.2 Vertical Reference Frames (2003 – 2007)

(Jointly by Commissions 1 and 2)

Main objectives of ICP1.2

- **provide the fundamentals for the installation of a unified global vertical reference frame and**
- **study the consistent modelling of both, geometric and gravimetric parameters for GVRS.**

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Outline

I. Status and Results of IAG ICP1.2 VRF

II. GVRS Definition

III. Realization of Vertical Reference Frames (VRF)

IV. Permanent Tide

V. Numerical Standards

VI. Conclusions

I. Status and Results of IAG ICP 1.2

- Final report of ICP1.2 with conclusions for continuation
- Draft Conventions for the Definition and Realization of a Conventional Vertical Reference System (CVRS)

- Draft CVRS conventions are
  - a general concept for the definition and realization of a GVRS
  - aligned to the IERS 2003 conventions structure and philosophy,
  - uses parts of the IERS 2003 conventions.

- ICP1.2 is recognizing the need for conventions for the definition and realization of an absolute gravity reference system (IGSN71 - IAG WG in preparation).

Contents of the Draft Conventions for the Definition and Realization of a CVRS

Deficiencies

- Establishment of an information system describing the various regional VRS and their relations to an GVRS.
- Clarifying the relationships between an GVRS and the ITRS: Basic relations between ITRS and GVRS conventions, parameters, realization, models, reductions).

II. GVRS Definition

The International Vertical Reference System (IVRS/GVRS) definition fulfils the following conventions:

1. **The vertical datum is defined as the equipotential surface for which the Earth gravity field potential is constant:**

   $$W_0 = \text{const.}$$

   (The vertical datum defines the relationship of the physical heights to the Earth body. Earth gravity field potential W_0 shall be conventional – realized by a conventional value.)

2. **The unit of length is the meter (SI). The unit of time is the second (SI). This scale is consistent with the TCG time coordinate for a geocentric local frame, in agreement with IAU and IUGG (1991) resolutions. This is obtained by appropriate relativistic modelling.**

3. **The vertical coordinates are the differences – ΔW_P between the potential W_P of the Earth gravity field at the considered points *P* and the potential of the CVRS conventional zero level W_0. The potential difference – ΔW_P is also designated as geopotential number c_P:**

$$-\Delta W_P = c_P = W_0 - W_P \,.$$

The potential difference can directly be derived by levelling in combination with gravity reductions, or indirectly by applying the disturbance potential in connection with geodetic space observations

$$W_P = U_P + T_P \,.$$

4. **The CVRS is a zero tidal system, in agreement with the IAG Resolution No 16 adopted in Hamburg in 1983.**

(A no-net-rotation condition is no necessary)

III. Realization of Vertical Reference Frames (VRF)

Two possible procedures:

$W_p = W_0 - c_p$ ***(levelling)*** *from an adjustment of a levelling network*

(only on continents)

$$H_n = \frac{c_P}{\bar{\gamma}}$$

$W_p = U_p + T_p$ ***(BVP)*** *from a new GGM (EGM07, or a combined CHAMP/GRACE models (CG01C))*

(general global)

$$\zeta = \frac{T_p}{\gamma_Q} = \frac{W_P - U_P}{\gamma_Q}$$

and GPS heights h_p

$$H_n = h_P - \zeta$$

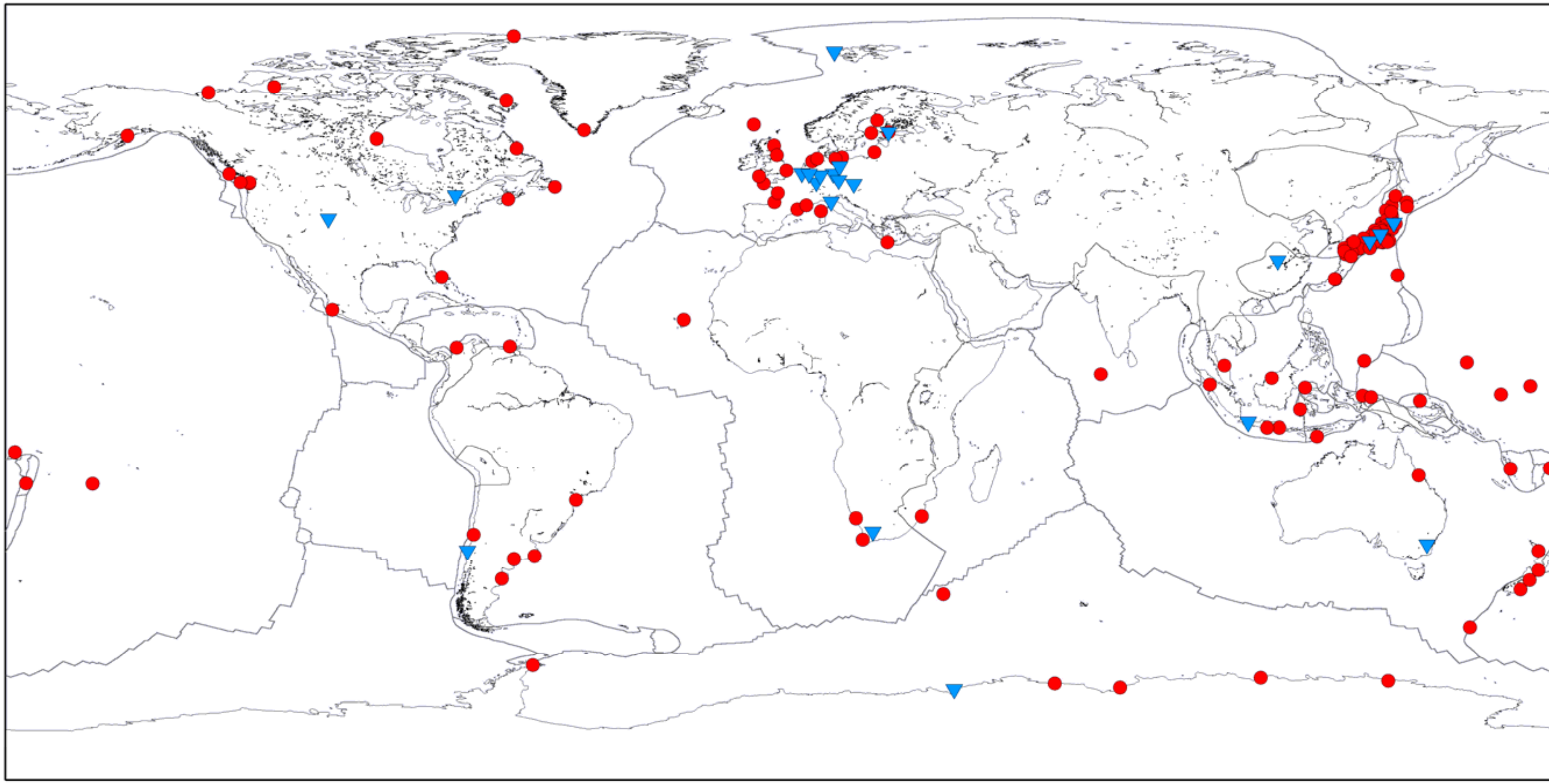
Realization of a Global Vertical Reference System

- GVRF recommendations

- **A global network of stations with geocentric coordinates in ITRS (chapter 4) and geopotential numbers referred to a global gravity model (GGM), which has to be geocentric**
- **The GGM for GVRS shall conventional (CGGM)**
- **ITRF and CGGM has to be based on a set of consistent conventional numerical standards (chapter 1.2).**
- **The GVRS level is realized by a conventional W_0 *value*.**
- **Changes of the vertical components can be observed with respect to the conventional GVRS level by relevant observation techniques: GNSS, tide gauges, permanent (SG) and periodical (AG) gravity stations.**

IVRF - an integrated network

Stations of IGS TIGA-PP and GGP (and absolute gravimeter)



● GPS/tide gauge stations ▼ super-conducting gravimeter stations

IV. Permanent tide

Vertical components and tidal systems

	gravity $g/\Delta g$	geoid W/N	levelling height ΔH	altimetry h	mean sea level msl	position X/h
Mean tidal system **Mean/zero crust** (Stokes is not valid if masses outsite the Earth surface)	Δg_m	N_m	ΔH_m	Relation to N_m for oceanographic studies	h_{msl}	
Zero tidal system **Mean/zero crust** (Recommended by IAG Res. No. 16, 1983)	Δg_z $\xrightarrow{\text{Stokes}}$	N_z (EGG97) CGGM	ΔH_z C_p GVRS			
Tide-free system **Tide-free crust** (unobservable, far away from the real earth shape – there is no reason for the non tidal/tide free concept)	Δg_n $\xrightarrow{\text{Stokes}}$	N_n (EGM96)				X_n ITRFxx, ETRS89

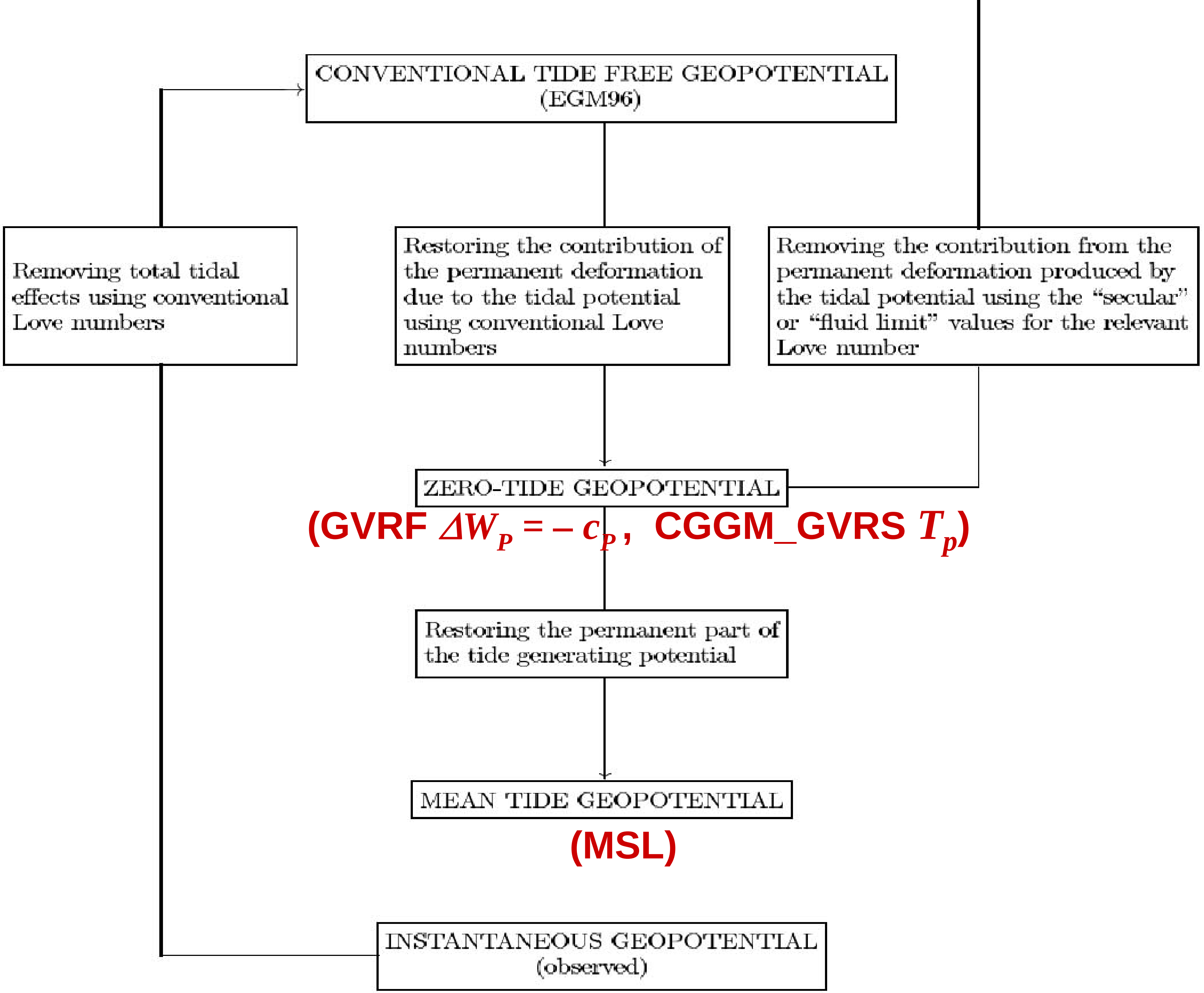


Figure 1.2. Treatment of observations for tidal effects in the geopotential (see Chapter 6).

V. Numerical Standards

Conflict:
In IERS 2003 conventions are two sets of parameters of a level ellipsoid in use: In chapter 1.2 numerical standards and in chapter 4. the GRS 80.

Geodetic Reference System 1980 (GRS 80) defines major parameters for geodetic reference systems related to a level ellipsoid

- **Agreed by IUGG, IAG and IAU.**
- **Recommended by IAG for the conversion of ITRF Cartesian coordinates to ellipsoidal coordinates.**
- **Worldwide use for many map projections and million of coordinates.**

Numerical Standards

- **At the IUGG General Assembly 1991 in Vienna new values for the geocentric gravitational constant GM and the semi-major axis a of the level ellipsoid were recommended.**

- **Since this time these parameters have been used in global gravity models e.g. EGM96**

Numerical Standards

IERS 2003 conventions

- defines numerical standards (chapter 1.2)
- recommends in chapters 4.1.4 and 4.2.5 recommended the use of GRS80 for transformations

➢ For global gravity models, various inconsistent values are used in practice

➢ The gravitational constants GM of GRS80 and IERS 2003 conventions differ in the metric system by about 0.9 m. The semi-major axis of both standards differs by 0.4 m.

Sets of conventional parameters (of level ellipsoids)

Ellipsoid	Semi-major axis a in m	Flattening f^{-1}	Geocentric gravitational constant GM in $10^8 m^3 s^{-2}$	U_0/W_0 in $m^2 \cdot s^{-2}$	γ_e in $m \cdot s^{-2}$	Remarks
Int. Ell. 1930 (Hayford)	6 378 388	297	3 986 329			
GRS 67	6 378 160	298.247	3 986 030			
GRS 80	**6 378 137**	**298.257222101**	**3 986 005**	***6 263 6860.850***	***9.78032 677***	**IERS 2003 Recom. in chapters 4.1.4 and 4.2.5**
WGS 84	6 378 137	298.25722356				
IUGG 91	6 378 136.3 0.5		3 986 004.41 0.01			
IERS 2003 Conventions (zero tide)	***6 378 136.6 0.1***	**298.25642 0.00001**	**3 986 004.418 0.008**	**6 263 6856.0 0.5 (Bursa et al.)**	**(9.78032 666)**	**IERS 2003 Num. stand. chapter 1.2**
EGM96 (tide free)	6 378 136.3		3 986 004.415			
EIGEN CG01C (tide free)	6 378 136.46		3 986 004.415			
ICP1.2, DGFI				**62 636 853,4 (Sanchez)**		

Angular velocity of the Earth rotation ω **7 292 115** 10^{-11} rad s^{-1}

Numerical Standards

IAG ICP1.2 recommends:

- **The IAG needs to remove this inconsistency in view to the development of integrated geodetic applications (cf., Hipkin, 2002).**

- **Investigations if there is a need change the W_0 value?**

Should the W_0 value be changed?

Carl Calvert, EUREF 2007

The consequences have to be considered!

VI. Conclusions

- **Realization of a GVRS is mainly a combination of different products of existing IAG services**
- **IAG has to clarify inconsistencies in the numerical parameters and data reduction for integrated geodetic applications in the IERS Conventions**
- **Draft GVRS conventions are available for consideration**
- **Where is the right place for GVRS conventions – IERS conventions?**
- **Continuation of work – proposed is an IAG Inter-Commission Working Group for GVRS**
- **Development of parts of IERS conventions to an International Standard? (numerical standards)**