IAG ICP1.2 Vertical Reference Frames

Minutes of the Project Meeting

IAG Scientific Assembly 2005, Dynamic Planet

Cairns, Australia

Meeting place: IAG Scientific Assembly 2005, Cairns, Congress Centre

Begin: August 22, 2005, 06:00 p.m.; **End:** 07:30 p.m.

Participants of the meeting: Ruth Adams, Matt Amos, Susana Barbosa, Dorata Brzezinska, Alessandro Capra, Joana Fernandes, Georgia Fotopoulus, Petr Holota, Jianliang Huang, Johannes Ihde, Bill Kearsley, Jan Krynski, Jaakko Mäkinen, Urs Marti, Markku Poutanen, Daniel R. Roman, Laura Sanchez, Zdislav Šima, Viliam Vatrt, Marie Vojtiskova,

ICP1.2 Members see Annex 1

Agenda

(1) Objectives, Status of Work, Expected Results

(2) Conventional Vertical Reference System and Frame (CVRS, CVRF)
- Definition of WHS (IVRS): Conventions for datum, codes, time dependent variations, parameters
- Realization of WHS (IVRF): Conventions and specification for procedures of computations (data reductions, selections of alternative procedures), selection of data, station distribution.

(3) Realization of IVRF
- Realization of WHF datum (parameters) and WHF prototype (IVRFyy)
- Relationship between existing VRF and IVRFyy (Unification, transformation parameters)
- Combination of IVRF and ITRF (consistency).

(4) Service and outreach
- WHF Meta data information system
- Cooperation with other IAG sub-commissions and projects
- Publications, papers, posters and leaflet
- Homepage?

(5) Varia, further actions

(6) Dinner 8.00 p.m.

Presentations:

Laura Sanchez: Empirical Determination of W_0 (Annex 6)

Viliam Vatrt : Progress Report of Special Study Group Global Geodesy Topics: Satellite Altimetry Applications (Annex 7)

(1) Objectives, Status of Work, Expected Results of ICP1.2

Based on the classical and modern observations, the ICP1.2 on Vertical Reference Frames shall study the consistent modelling of both, geometric and gravimetric parameters, and provide the fundamentals for the installation of a unified global vertical reference frame.

The following aspects shall be mentioned summarizing:

Motivation

- IAG Project Global Geodetic Observing System – GGOS
- Vertical Systems are the natural frame and application for combination of geodetic space techniques and gravity
- New experiences of IAG regional sub-commissions in field of height reference system unification
- Results of satellite gravity missions available
- New set of parameters in a higher accuracy level is available (IERS conventions 2003).

Objectives

- Elaboration of a proposal for the definition and realization of a global vertical reference system (World Height System – WHS);
- Derivation of transformation parameters between regional vertical reference frames;
- Establishment of an information system describing the various regional vertical reference frames and their relation to a world height frame (WHF).

Program of Activities

- Harmonization of globally used height data sets;
- Study of combination procedures for height data sets from different techniques;
- Study of information on regional vertical systems and their relation to a global vertical reference system for practical applications;
- Unification of regional (continental) height systems.

Actions of IAG ICP1.2 Porto Meeting, August 31, 2004 Porto, Portugal

A result of the controversial discussion about the definition and realization of a global vertical reference system was the composition of two work packages.
The first work package will address

- *convention and standards for a Conventional Height System, a World Height System and a World Height Frame*
- *relationship to the CTRS, CTRF and gravity standards*
- *datum realization (handling of information of the satellite altimetry, possible role of the TIGA project, mean earth ellipsoid versus W_0)*

This work package will be in executed in collaboration of J. Ihde, J. Krynski, J. Mäkinen and V. Vatrt.

The second work package is related to the

- *unification of height systems and*
- *collection and distribution of information about the different national height systems including transformation parameters.*

Members of the group are M. Amos, A. Kasenda, Bill Kearsly, G. Liebsch, D. Roman and M. Veronneau.

Contributions/Papers

A. Ardalan et al.: *Global Height Datum Unification: A new approach in the gravity potential space.*

A. Ardalan et al.: *New Global Estimates of the Geoid's Potential Value, Sea Surface Topography, and the Geoid based on 11 years of Topex/Poseidon Satellite Altimetry Data.*

A. Ardalan et al.: *A new global ocean tide model based on orthonormal base functions and 11 years of Topex/Poseidon satellite altimetry data*

M. Bursa et al.: *Geopotential for Specifying Relativistic Amomic Time Scale and Global Vertical Reference System*

M. Bursa et al.: *Determination of Geopotential $W_{0,Alicante}$ AT Alicante LVD and its Connection to NAVD88, and IGN69 LVDs. Progress Report (July 2005)*

M. Bursa et al.: *A Global Vertical Reference Frame GVRF05*

J. Ihde, L. Sanchez: A Unified global height reference system as a basis for IGGOS

J. Ihde et al.: *Transformation Parameters between European Height Reference Frame and pan-European EVRS*

J. Mäkinen: *Some remarks and proposals on the re-definitionof the EVRS and EVRF*

L. Sanchez: *Definition and realization of the SIRGAS vertical reference system within a globally unified height system*

(2) Conventional Vertical Reference System and Frame (CVRS, CVRF)

The conventions for the definition and realization of a WHS shall be aligned to the IERS 2003 Conventions.

The IERS 2003 Conventions already basically contain the current parameters and procedures for reduction of coordinates. For the specifications of a WHS the parameters and procedures should be checked in detail within the next 2 years whether they meet the demands.

So it should be considered whether the value for W_0 that was derived by Bursa and included into the IERS Conventions should be maintained or current results like e.g. from Ardalan should be included.

All other relevant numerical values have to be considered.

The following tasks need to be realized:

- Definition of WHS (IVRS): Conventions for datum, codes, time dependent variations, parameters
- Realization of WHS (IVRF): Conventions and specification for procedures of computations (data reductions, selection of alternative procedures), selection of data, station distribution.

Generally the following approach is apparent:

- The level of a WHS is fixed to W_0.
- The height component (coordinates, codes) are differences of the Earth's gravity potential. It can be determined by levelling or from differences between GPS heights and a global gravity model, representing the mean geoid.
- The parameters, codes and the observations of the WHS have to be consistently related to the Zero Tidal System.

CVRS Conventions (Definition)

The Conventional Vertical Reference System (CVRS) is a gravity-related height reference system. It is defined by the following conventions:

a) The vertical datum is the zero level of which the Earth gravity field potential W_0 is equal to the normal potential of the mean Earth ellipsoid U_0:

$$W_0 = U_0.$$

datum

geocentric, including oceans and atmosphere

W_0 independent from the tidal system

b) The height components are the differences ΔW_P. between the potential W_P of the Earth gravity field through the considered points P and the potential of the CVRS zero level W_0. The potential difference - ΔW_P is also designated as geopotential number c_P:

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

Normal heights are equivalent to geopotential numbers.

coordinate system

SI units
$m^2 \cdot s^{-2}$

$W_P = U_P + T_P$ *(BVP)*
$W_P = W_0 - c_P$ *(levelling)*

c) The CVRS is a zero tidal system[1], in agreement with the IAG Resolutions No 16 adopted in Hamburg in 1983

frame

[1)] In a) and b) the potential of the Earth includes the potential of the permanent tidal deformation but excludes the permanent tidal potential itself.

(3) Realization of IVRF

Comparable to the ITRS 2003 conventions standards for the realization procedures of a WHS have to be fixed. Special items are:

- Realization of WHF datum (parameters) and WHF prototype (IVRFyy)
- Relationship between existing VRFs and IVRFyy (Unification, transformation parameters)
- Combination of IVRF and ITRF (consistency).

Generally the following approach for the realization of physical height systems is apparent:

1) $W_P = U_P + T_P$ *(BVP)*

For a WHS applicable

from a new GGM (IAG2005, or a combined CHAMP/GRACE model - CG01C)

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

and GPS heights h_P

$$H_n = h_P - \zeta$$

2) $W_P = W_0 - c_P$ *(levelling)*

from an adjustment of a levelling network

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

The following approach for the unification of height reference systems (derived by levelling) is apparent:

- Generally and globally applicable is the unification with a global gravity model (GGM) and GPS/levelling points. At the GPS/levelling points a high resolution gravity model related to a GGM is useful. A specific solution of a GGM should be recommended as conventional model, to realize a uniform unification.

  $H = h(GPS) - N(GGM)$ in any point

- Reducing tide gauge observations by the mean sea surface topography (SST) to a GGM.

  $H = h(TG/MSL) - MST(ALT,GGM)$ in tide gauges

- Furthermore the unification of height reference systems can be realized by connecting levellings (applicable only on continents).

Combination of the single procedures is, if possible, useful.

(4) Service and outreach

The following items were discussed
- Development of a WHF Meta data information system
- Cooperation with other IAG sub-commissions and projects and FIG
- Publications, papers, posters and leaflet
- Installation of Homepage

(5) Actions

Conventions for WHS definition and realization (CVRS, CVRF) – structure and editorial staff:

The Conventions for WHS definition and realization (CVRS, CVRF) shall have the a structure following IERS conventions 2003:

1.	General Definitions and Numerical Standards	
1.1	Permanent Tide	(Markku Poutanen)
1.2	Numerical Standards	(Proposed: Milan Bursa, tbd)
2.	CVRS and CVRF	
2.1	Concepts and Terminology	(Johannes Ihde)
2.1.1	Basic Concepts	
2.1.2	IVRS	
2.1.3	IVRF	
2.2	IVRF products	
3.	Relations between IVRS and ITRS	(Johannes Ihde)
4.	Relations between IVRS and regional and local VRS.	(Johannes Ihde)

- Bibliography
  All member of ICP1.2 WG were asked to inform Johannes Ihde about relevant publications and send him the bibliographic information
- Meta data information system
  BKG will prepare a template for selecting meta data following the content of the CRS-EU information system

(6) Varia

- ICP1.2 Workshop in spring 2006, fixed for April 10/11, 2006 in Prague
  Invitation and agenda will followed till end of 2005
- ICP1.2 meeting at GGSM2006 in September 2006 in Istanbul

Keeper of the Minutes: Johannes Ihde, Daniel R. Roman

Annex 1

ICP1.2 Members

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Simek, Jaroslav	Czech Republic
Vatrt, Viliam	Czech Republik
Véronneau, Marc	Canada
Vojtiskova, Marie	Czech Republik
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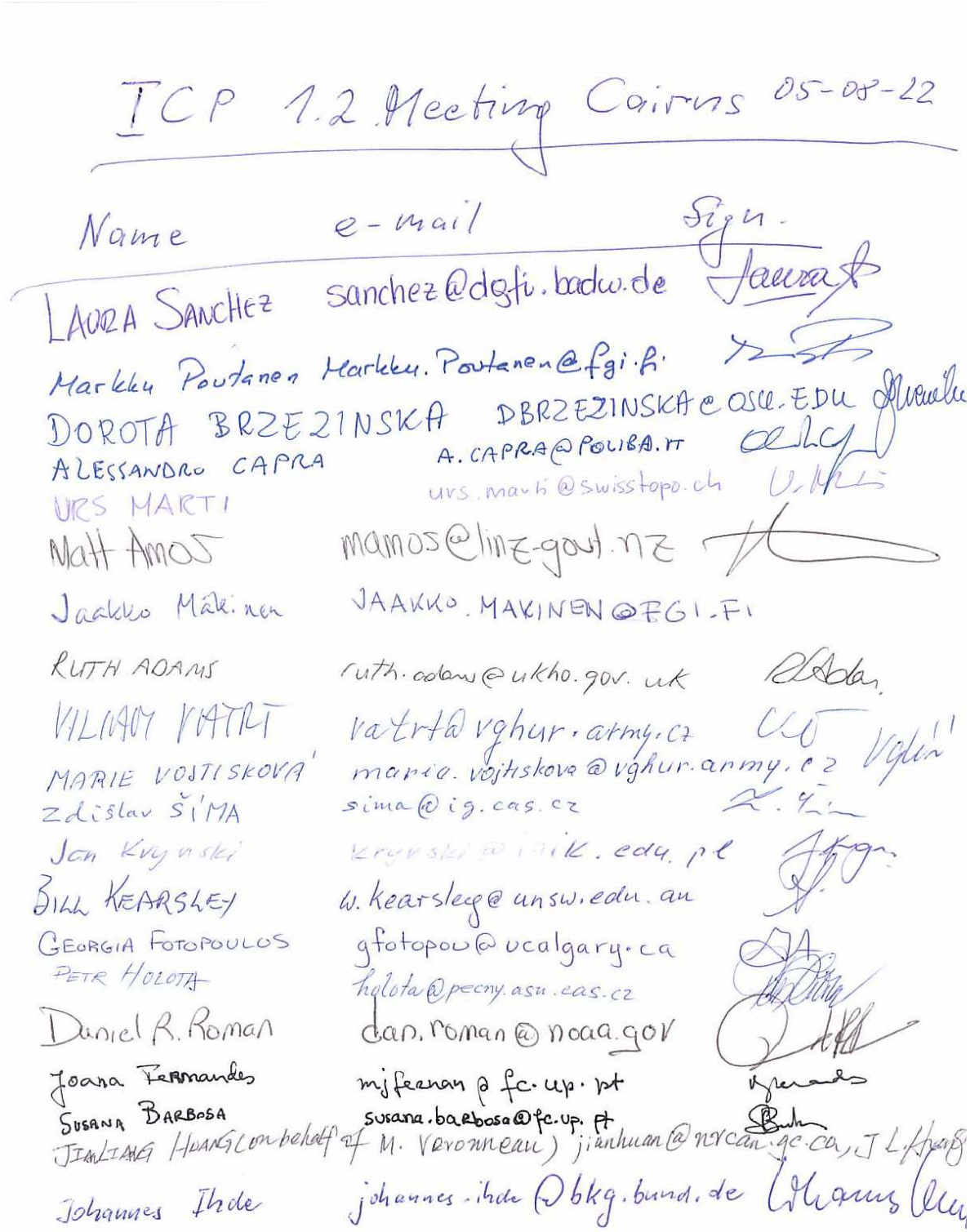
Annex 2



ICP 1.2 Meeting Cairns 05-08-22

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Annex 3

Relations between ITRS and IVRS/WHS (conventions, parameters, realization)

ITRS		WHS/IVRS
IUGG Resolution No. 2, Vienna 1991		IAG ICP1.2 Vertical Reference Frames
	origin	
Explicit	Geocentric, the center of mass being defined or the whole Earth, including oceans and atmosphere.(At present no convention related to the motion of the geocentre)	Implicit
	orientation	
Initial BIH orientation. Non-rotating system. No global residual rotation with respect to horizontal motions at the Earth´s surface.		No necessary convention
	units-scale	
SI unit meter The ITRS scale consistent with the Geocentric Coordinate Time (TCG)		SI units meter and seconds $W_0 = U_0$ The scale of the Earth body W_0 is approximated by the normal potential of the mean Earth ellipsoid U_0 which includes the masses of the oceans and the atmosphere.
	coordinates	
quasi – Cartesian system X		potential of the Earth gravity field W_P = W(X) $= U_P + T_P$ (GPM) $= W_0 - c_P$ (Levelling)
	system parameters	
		mean Earth ellipsoid (U_0, GM, J_2, w)
	realization	
ITRF 2000 tide-free		EVRF 2000 (UELN 95/98, ETRS89) $W_P = W_{NAP} + c_P$ (Levelling) zero tidal system (?) GRS 80

Annex 4

Height Components and Tidal Systems

	gravity **g/Δg**	**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 Stokes → N_Z (EGG97)		ΔH_Z c_p			
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 Stokes → N_n (EGM96)					X_n ITRFxx, ETRS89

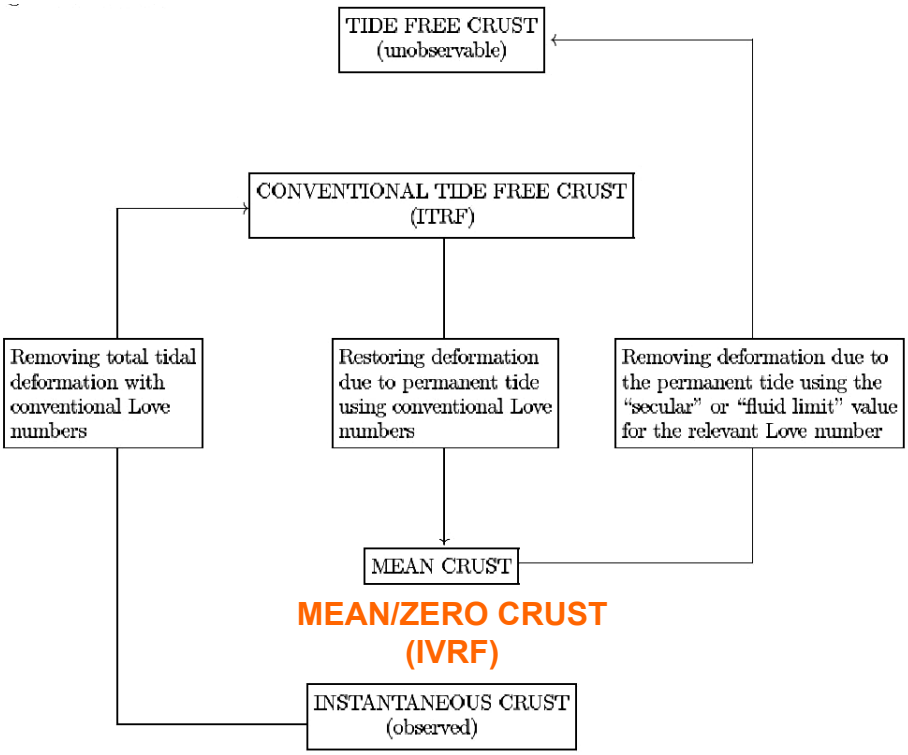


Figure 1.1. Treatment of observations to account for tidal deformations in terrestrial reference systems (see Chapters 4 and 7).

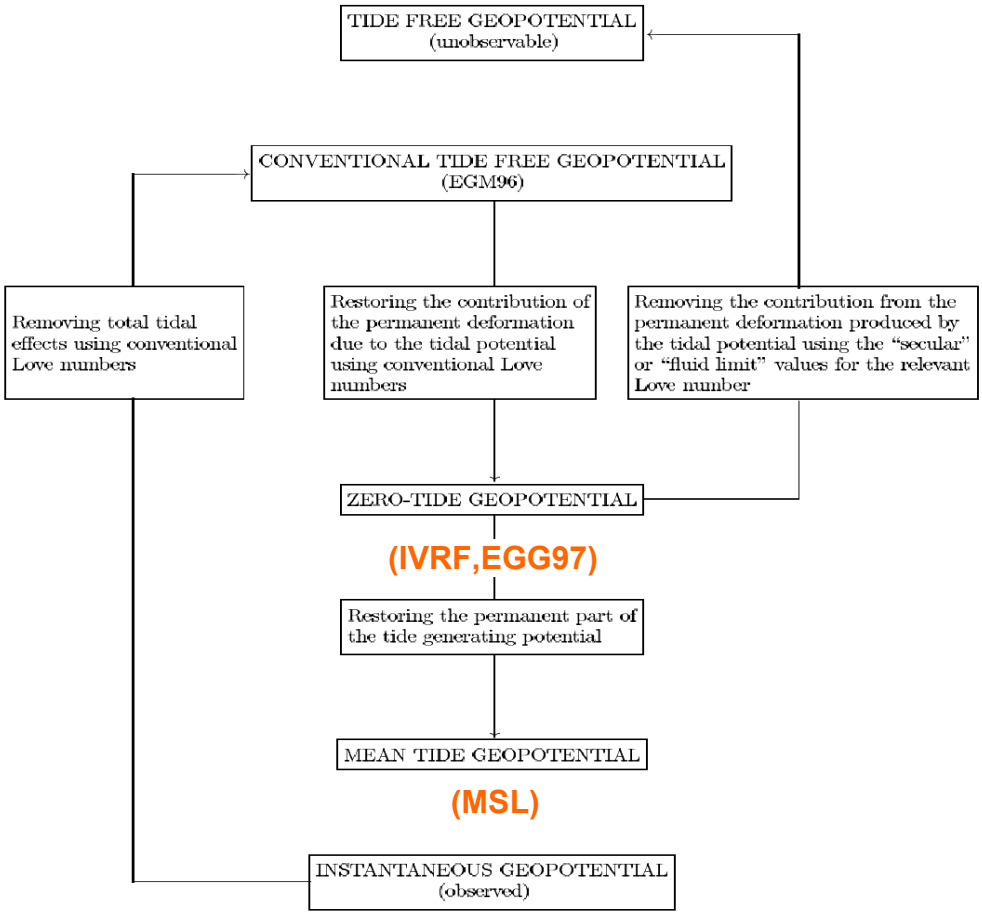


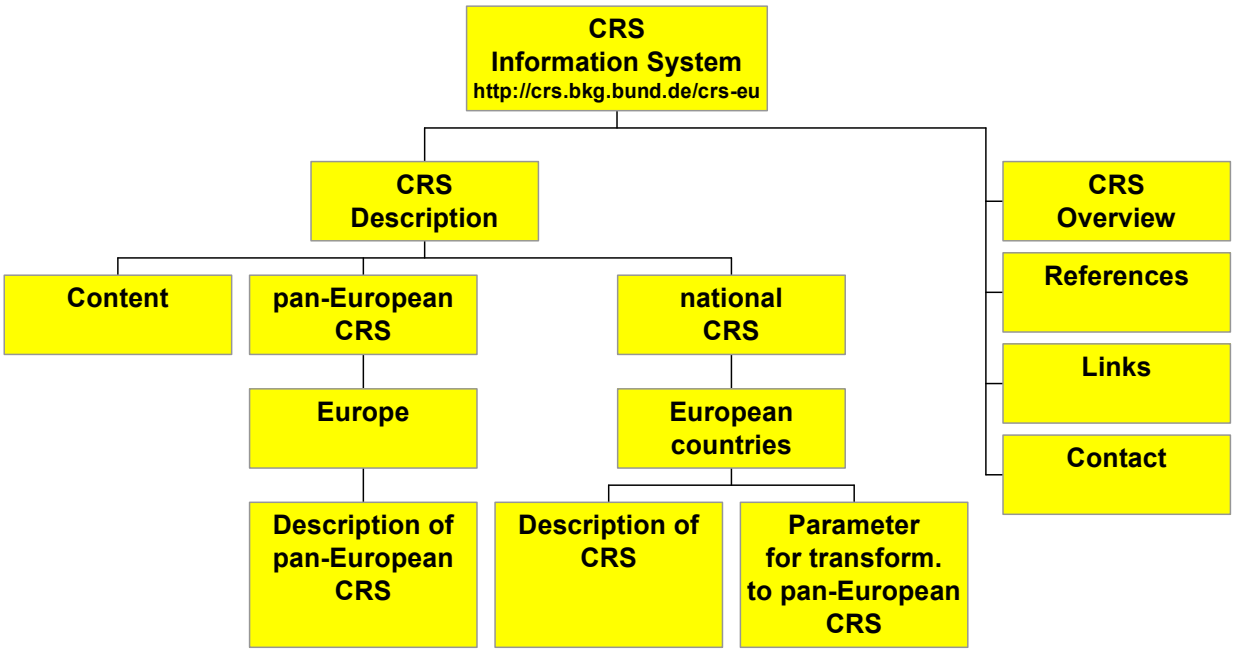
Figure 1.2. Treatment of observations for tidal effects in the geopotential (see Chapter 6).

(from IERS Conventions 2003)

Annex 5

The Information System for European Coordinate Reference System (CRS-EU) (meta data)

http://crs.bkg.bund.de/crs-eu



Content for gravity related heights

- descriptions of national height reference systems
- description of pan-European CRS for height – EVRF2000
- transformation parameters for height from national systems to EVRF2000

The information
- were prepared by BKG and agreed with NMA
- or provided from the National Mapping Agencies (NMA) themselves
- always unified and prepared regarding ISO-Standard 19111:2003

Available EVRS transformation parameters from levelling

Country	Verification by the country	identical points	Parameters			RMS	residual deviations	
		number + kind	translation in cm	incl. in latitude in cm / 100km	incl. in longitude in cm / 100km	in cm	min in cm	max in cm
AT	x	114 UELN	- 35.6	- 2.8	- 2.8	3.1	-6.1	+6.1
BA/HR		40 UELN	- 34.5	- 0.3	- 0.9	0.7	-1.0	+1.4
BE	x	4 EUVN	- 231.1	- 0.8		0.2	-0.2	+0.2
BG	x	36 UELN	+ 18.2	+ 0.1	- 0.2	0.2	-0.6	+0.4
CH (LN02)	x	225 UELN	- 24.5	- 10.2	- 1.6	3.3	-8.6	+9.4
CZ		53 UELN	+ 11.6	+ 1.7		1.4	-3.5	+2.8
DE (DHHN92)	x	443 UELN	+ 1.4	- 0.1		0.2	-0.7	+0.6
DK	x	707 UELN	+ 1.1	+ 0.1	+ 0.5	0.3	-0.9	+0.8
EE	x	36 UELN	+ 13.3	- 0.7	+ 0.2	0.3	-0.5	+0.5
ES	x	70 UELN	- 48.6	- 0.2	+ 0.3	1.0	?	?
FI		66 UELN	+ 21.3			0.3	-0.7	+0.9
FR	x	8 EUVN	- 48.6			0.5	-0.4	+1.0
GB	x	5 EUVN	+ 8.1	- 2.7	- 1.1	1.9	-1.2	+2.2
HR		40 UELN	- 34.5	- 0.3	- 0.9	0.7	-1.0	+1.4
HU	x	35 UELN	+ 14.0	+ 0.4	- 0.1	0.3	-0.7	+0.6
IT		9 EUVN	- 35.3	+ 0.2	+ 0.3	0.7	-0.6	+1.1
LT	x	46 UELN	+ 10.2		+ 0.1	0.2	-0.2	+0.3
LV		123 UELN	+ 10.5		+ 0.2	0.7	-2.0	+2.2
NL	x	757 UELN	- 0.5			0.2	-2.1	+0.4
NO	x	117 UELN	- 0.1	- 0.5	+ 1.7	3.7	-7.6	+7.0
PL		98 UELN	+ 16.0	+ 0.5		0.5	-2.0	+0.9
PT	x	5 EUVN	- 31.5			1.3	-1.4	+2.1
RO		46 UELN	+ 2.8	+ 0.1	+ 0.1	0.2	-0.5	+0.9
SE		21 EUVN+TideG	+ 1.0	- 0.6		1.1	-2.3	+2.0
SI	x	9 UELN	- 41.1	- 1.6	+ 0.4	0.3	-0.4	+0.4
SK		3 EUVN	+ 12.2	+ 1.0		0.2	-0.1	+0.1

Annex 6

Empirical determination of W_0

Gauss-Listing definition:

$$\int_{S_O} (W - W_0)\, dS_O = \min$$

S_O global ocean surface

$$W = \frac{GM}{r}\left[1 + \sum_{n=1}^{\infty}\sum_{m=0}^{n}\left[C_{nm}\cos m\lambda + S_{nm}\sin m\lambda\right]P_{nm(\cos\theta)}\right] + \frac{1}{2}\omega^2 r^2 \cos(90° - \theta)$$

Constants → GM, ω
Mean Sea Surface (MSS) model → (r, θ, λ)
Global Gravity Model (GGM) → C_{nm}, S_{nm}

W_0 – values from different GGMs and MSS-models

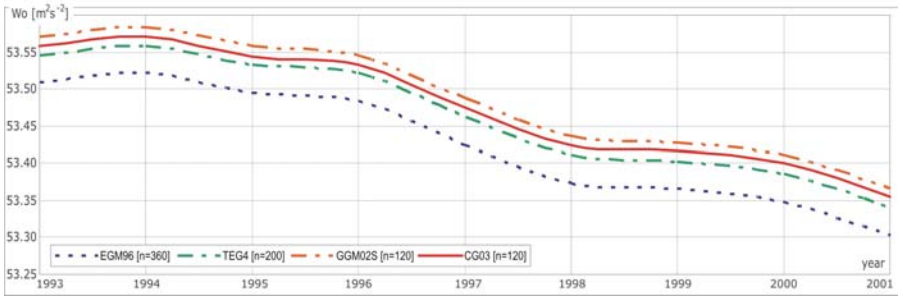
MSS	n	EIGEN-CG03C	EGM96	TEG4	GGM02S	φ [N/S]
CLS01	120	62 636 853,35	62 636 853,37	62 636 853,38	62 6368 53,36	60/60
	200	53,35	53,37	53,37		60/60
	360	53,35	53,36			60/60
KMS04	360	53,24	53,26			60/60
GSFC00.1	360	53,58	53,59			60/60
CLS01	120	62 636 854,61	62 636 854,62	62 636 854,65	62 636 854,61	82/80
	200	54,61	54,62	54,64		82/80
	360	54,61	54,61			82/80
KMS04	360	54,46	54,45			82/82
GSFC00.1	360	54,93	54,93			80/80

MSS-Models:
- CLS01 (Hernandez and Schaeffer 2001)
- KMS04 (Andersen et al. 2004)
- GSFC00.1 (Koblinsky et al. 1999)

GGMs:
- EGM96 (Lemoine et al. 1998)
- TEG4 (Tapley et al. 2001)
- GGM02 (Tapley et al. 2005)
- EIGEN-CG03C (Förste et al. 2005)

Conventions for the determination of W_0

d) Time dependence of W_0



MSS : DGFI yearly MSSs (1999-2001) from AVISO T/P data
+ FES2004 tidal solution (Lettelier et al. 2004)
+ Chamber et al. (2003) sea state bias.

A reference epoch shall be adopted: GGM's coefficients and MSS-heights should be reduced to the same epoch.

Recommendation

GGM: EIGEN-CG03C, n = 120 at 2000.0

MSS-model: From T/P, between φ = 60°N/S, with 1° x 1° resolution at 2000.0

Constants: GM = 398 600,4415 x 10^9 m^3s^{-2}; ω = 7 292 115 x 10-11 rad s^{-1}

Procedure: Gauss-Listing definition, empirical evaluation of the actual gravity potential at MSS-heights and W,-values averaged using *cos* φ as a weight.

W_0 = 62 636 853,4 m^2s^{-2}

Some comments about W_0 (I)

- The reference W_0-value can be arbitrarily selected, but it is preferred that it is derived from actual observations of the Earth's gravity field and of the sea surface.

- The *state of the art* allows the empirical determination of W_0; the traditional solution of supposing W_0 identical to a predetermined normal potential U_0 is no longer required.

- As any reference system, W_0 should be based on some adopted conventions, which guarantee its reliability and repeatability.

- The W_0-value presented here was computed following a basic approach without complicated theoretical formulations.

Some comments about W_0 (II)

- The reliability of the W_0-value presented here is proved by using several combinations (spatial and spectral resolutions) of four different GGMs with four different MSS-models.

- The GM-value used here corresponds to the Terrestrial Time (TT). By using the GM in Geocentric Coordinate Time (TCG), W_0 changes by ~ 1×10^{-9}, i.e. ~ 0,06 m^2s^{-2}.

- The recommended W_0-value differs by ~ 3 m^2s^{-2} (~ 4×10^{-8}) from other global computations (e.g. Bursa et al. 1997, 1999, 2000, 2002, 2004 and recently Ardalan et al. 2005). The reasons for this disagreement are not clear yet. It is necessary to compare in detail the Bursa et al. and Ardalan et al. methodologies applied and the GMMs and MSS-models used to find the divergence.

Annex 7

PROGRES REPORT

Special Study Group Global Geodesy Topics: Satellite Altimetry Applications (SSG GGSA), July 2005.

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IAG ICP1.2 Working Group Meeting
on occasion of the IAG Scientific Assembly in Cairns
Monday, 22 August 2005

Main activities of SSG GGSA within IAG ICP-1.2 (September 3, 2004 – Porto- to August 22, 2005)

- -development of Global Vertical Reference Frame (continuation)
- -presentation SSG GGSA at Geographic conference of NATO, Brussels 2005
- -a joint Project of Instituto de Astronomia y Geodesia (UCM-CSIC) Madrid (M. J. Sevilla), and (SSG GGSA)

Paper for IAG Scientific Assembly in Cairns

"GEOPOTENTIAL FOR SPECIFYING RELATIVISTIC ATOMIC TIME SCALE AND GLOBAL VERTICAL REFERENCE SYSTEM"

- The paper was presented on August 22, 2005 (morning)
- Copies of presentation are available
- Here, only the main ideas will presented

- On the basis of T/P data during 1993-2003, we have determined the value of W_0, the rounded value is

$$W_0 = (62\ 636\ 856.0 \pm 0.5)\ m^2\ s^{-2}$$

- This rounded value W_0 has already been adopted by the IAU for the definition of the constant $L_G = W_0/c^2$ (for the realization of the relativistic Atomic Time scale.

Investigation the long-term variation in W_0

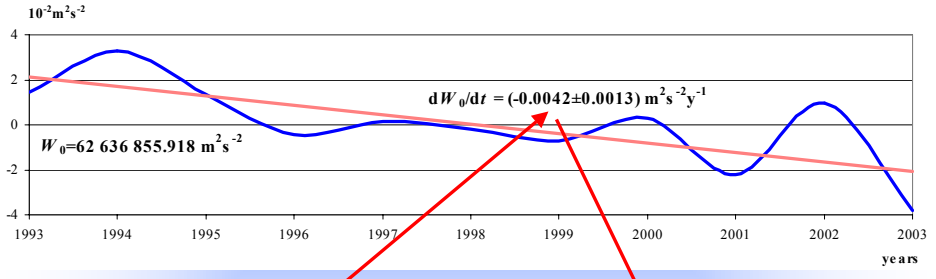
The long-term variations in W_0 have been investigated on the basis of T/P data during 1993 - 2003

-solution I : No inverted barometer correction applied

-solution II : Inverted barometer correction applied

SOLUTION I:

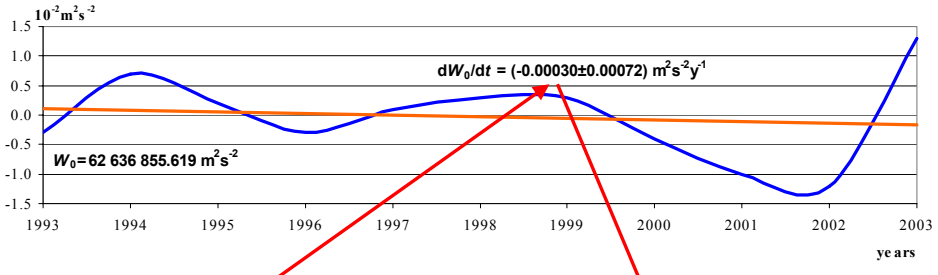
LONG-TERM VARIATION OF W_0: NO INVERTED BAROMETER CORRECTIONS APPLIED



The rate of W_0 is not significant with respect to the adopted standard deviation $\pm 0.5\ m^2 \cdot s^{-2}$ of W_0

SOLUTION II:

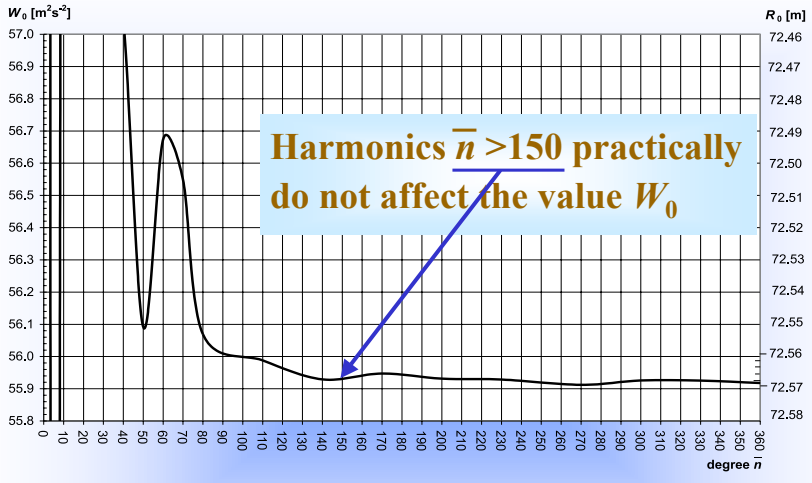
LONG-TERM VARIATION OF W_0, INVERSE BAROMETER CORRECTION APPLIED (MODEL AVISO)



The rate of W_0 is again not significant with respect to the adopted standard deviation ±0.5 $m^2 \cdot s^{-2}$ of W_0

RECENT W_0 -VALUES DETERMINED ON THE BASIS OF DIFFERENT GEOPOTENTIAL MODELS

Geopot. model	n	W_0 [$m^2 \cdot s^{-2}$]	rms [$m^2 \cdot s^{-2}$]
EGM96	360	62 636 855.918	±0.005
GRACE -GGM02C	200	62 636 855.832	±0.005
GRACE EIGEN-CG01	360	62 636 855.883	±0.005



Dependence of W_0 (62 636 800 m²s⁻² subtracted) and R_0 (6 363 000 m subtracted) on degree $\bar{n}$ of harmonics retained; geopotential model EGM96

Derived parameters of the Earth's mean ellipsoid and its gravity field.

Tidal System	J_2 [10^{-10}]	a [m]	$1/\alpha$ [10^{-5}]	γ_e [mGal]	β [10^{-8}]	$-\beta_1$ [10^{-8}]	w_0 [10^{-9}]
Zero	10 826 359 ± 1	6 378 136.58 ± 0.10	298 256 45 ± 1	978 032.67 ± 0.05	530 243 ± 8	582	3 194 711 525 ± 1
Mean	10 826 667 ± 1	6 378 136.68 ± 0.10	298 252 33 ± 1	978 032.69 ± 0.05	530 238 ± 8	582	3 194 704 607 ± 1
Tide-free (k_2= 0.301 9)	10 826 267 ± 1	6 378 136.55 ± 0.10	298 257 68 ± 1	978 032.67 ±0.05	530 245 ± 8	582	3 194 713 591 ± 1

Adopted:

$GM = (398\,600\,441.8 \pm 0.8) \times 10^6\ m^3 \cdot s^{-2}$,

$\omega = 7\,292\,115 \times 10^{-11}\ rad \cdot s^{-1}$,

$J_2 = (1\,082\,635.9 \pm 0.1) \times 10^{-9}$,

$W_0 = 62\,636\,856.0\ m^2 s^{-2}$

Geopotential W_0
- a fundamental geodetic constant suitable to specify a Global Vertical Reference System (GVRS)

-Because the rate of W_0 is not significant the rounded value of W_0 can by also adopted to specify the GVRS

-the numerical value

$W_0 = (62\ 636\ 856.0 \pm 0.5)\ m^2 s^{-2}$

should be preferred, because it has already been used for the definition of the constant L_G (adopted at IAU XXIVth General Assembly (2003)

MAIN CONCLUSIONS

-The mean geopotential value W_0 of the mean ocean surface may be adopted for specifying the Earth's dimension

-The rounded value $W_0 = 62\ 636\ 856.0\ m2 \cdot s{-}2$ is preferable, because it has already been adopted by the IAU for *LG* - value, which was specified as a defining constant

-No perturbing function, which is globally harmonic, does affect W_0.

MAIN CONCLUSIONS(Cont'd)

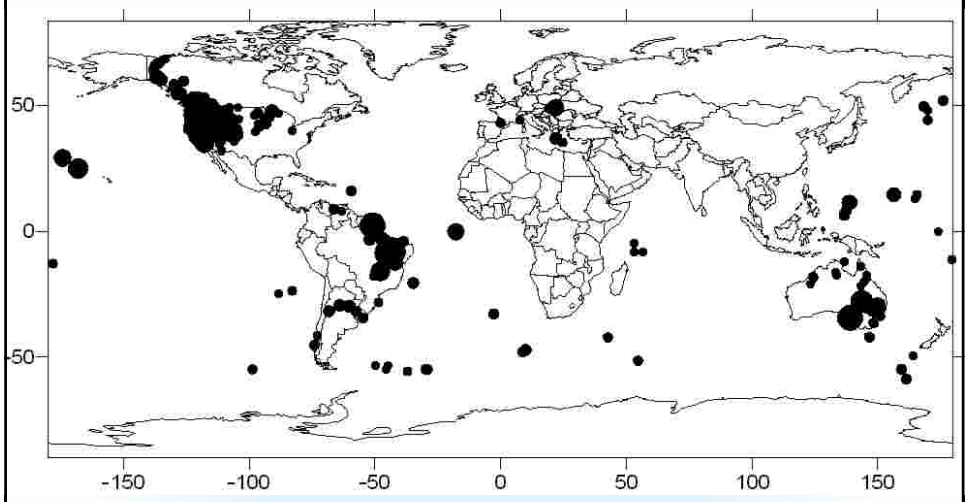
-Due to its simplicity and uniqueness a global gravity field model is preferred for GVRS specification/realization as well as for LVD connections,

-Locally improved gravity fields increase complexity and may introduce additionally biases and computational ambiguities

PRESENTATION of SSG GGSA AT THE GEOGRAPHIC CONFERENCE NATO, BRUSSELS 2005

LVD shifts based on GPS/leveling data and geopotential models GRACE and EGM96

LVD i	Number of testing sites	$W_{0,i}$ [m^2s^{-2}] (62 636 000 m^2s^{-2} subtracted)			LVD shifts [cm] related to W_0=62 636 856.0 m^2s^{-2}		
		EIGEN-CG01 n = 360	GGM02C n = 200	EGM96 n = 360	EIGEN-CG01 n = 360	GGM02C n = 200	EGM96 n = 360
NAVD88 Rimouski	6 475	861.27 ± 0.04	861.25 ± 0.06	861.20 ± 0.05	-53.6 ± 0.4	-53.3 ± 0.6	-52.8 ± 0.5
NAP Normaal Amsterdamsch Peil	80	858.76 ± 0.37	858.22 ± 0.41	857.08 ± 0.41	-28.0 ± 3.8	-22.5 ± 4.2	-11.0 ± 4.0
KHD Kronstadt	588	855.16 ± 0.12	854.90 ± 0.14	857.63 ± 0.13	8.5 ± 1.3	11.1 ± 1.4	-16.6 ± 1.3
AHD Johnston Geodetic Station	866	852.17 ± 0.15	852.58 ± 0.18	851.98 ± 0.18	38.9 ± 1.5	34.7 ± 1.8	+40.9 ± 1.8
BHD Imbituba	177	856.00 ± 0.60	854.99 ± 0.63	855.68 ± 0.66	0.0 ± 6.1	10.6 ± 6.4	+3.2 ± 6.7
IGN69 Marseille	973	862.10 ± 0.34	861.89 ± 0.35	862.68 ± 0.35	-62.0 ± 3.4	-59.8 ± 3.5	-67.9 ± 3.5



The 1m≤$|\delta R_i|$<3m values for EIGEN-CG01 depicted by circles of different diameters

A joint Project of
Instituto de Astronomia y Geodesia (UCM-CSIC) Madrid (M. J. Sevilla), and
SSG GGSA

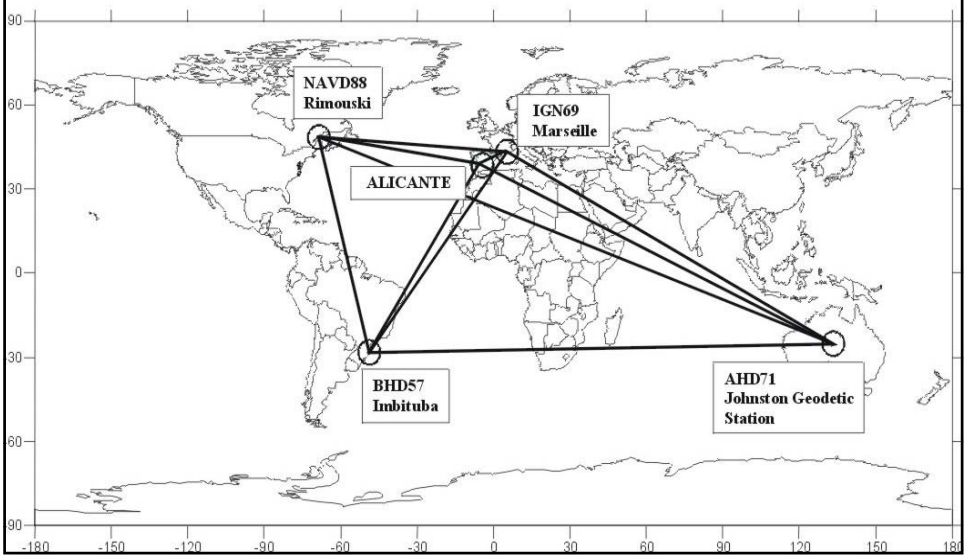
-Determiation of geopotential $W_{0,\text{ALICANTE}}$ at Alicante LVD and its connection to NAVD88, and IGN69 LVDs

-A global vertical reference frame GVRF05

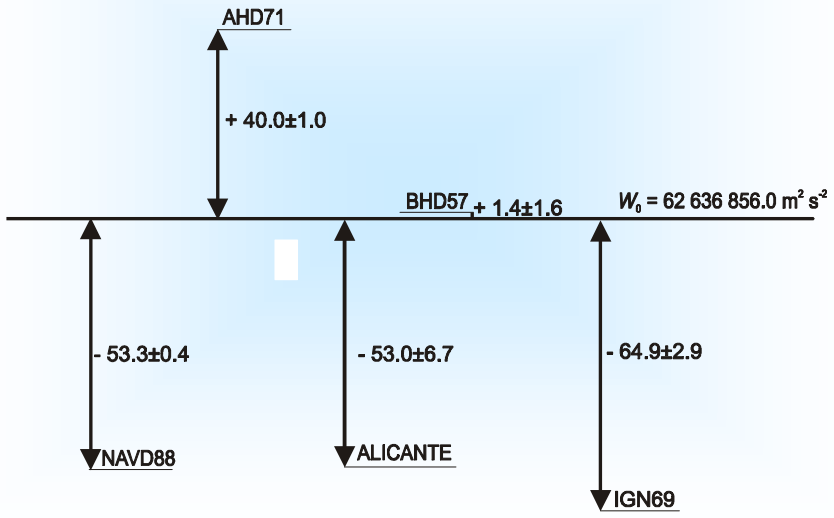
-The GVRF04 (2004) developed by the SSG GGSA was enlarged by adding the Local vertical Datum (LVD) of the Alicante Spanish national datum

-The geopotential value $W_{0,\text{ALICANTE}}$, determined on the basis of 303 GPS/leveling sites well distributed over the whole territory of Spain, makes it possible to include the Spanish $\text{LVD}_{\text{ALICANTE}}$ into the proposed GVRF

Global Vertical Reference Frame Status: June 2005



Vertical shifts (in cm) of LVD's realizing the GVRF05



-The Helmert orthometric heights over the territory of Spain were transformed to the Molodensky normal heights using the current SSG GGSA procedure

-Tidal corrections applied, i.e the tide-free model used.