Vertical datum standardisation: a fundamental step towards a global vertical reference system

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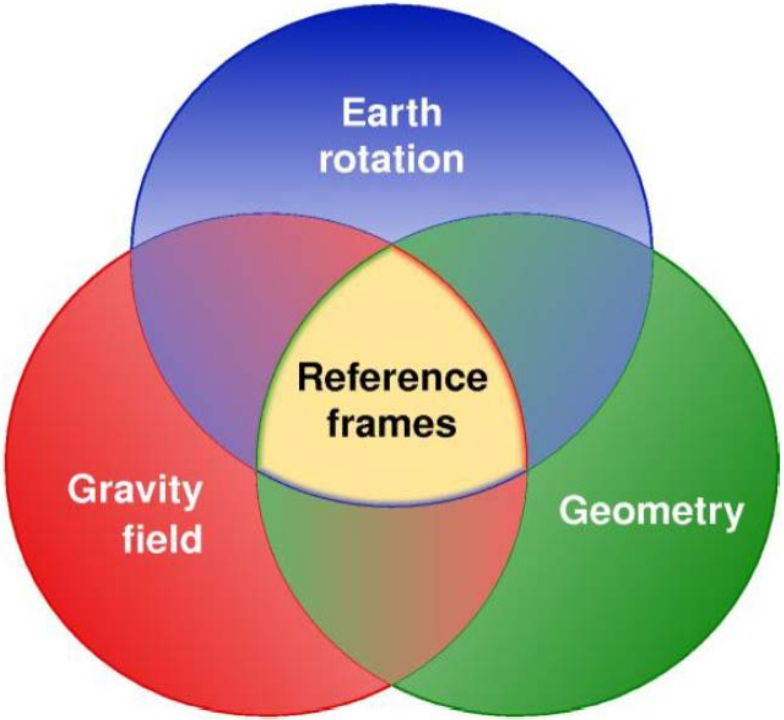
On behalf of the
Working Group on Vertical Datum Sandardisation

A common initiative of

GGOS Theme 1: Global Height System	International Gravity Field Service (IGFS)	IAG Commission 2: Gravity Field	IAG Commission 1: Reference Frames

GGOS: Global Geodetic Observing System

- GGOS is the contribution of Geodesy to a global Earth monitoring system;
- It was installed (2003) by the International Association of Geodesy (IAG) and participates in the Group on Earth Observation (GEO) and in the Global Earth Observation System of Systems (GEOSS).
- Main objectives:
  1) To provide the observations needed to monitor, map and understand changes in the Earth's shape, rotation and mass distribution;
  2) To provide the **global frame of reference** for measuring and consistently interpreting global change processes.

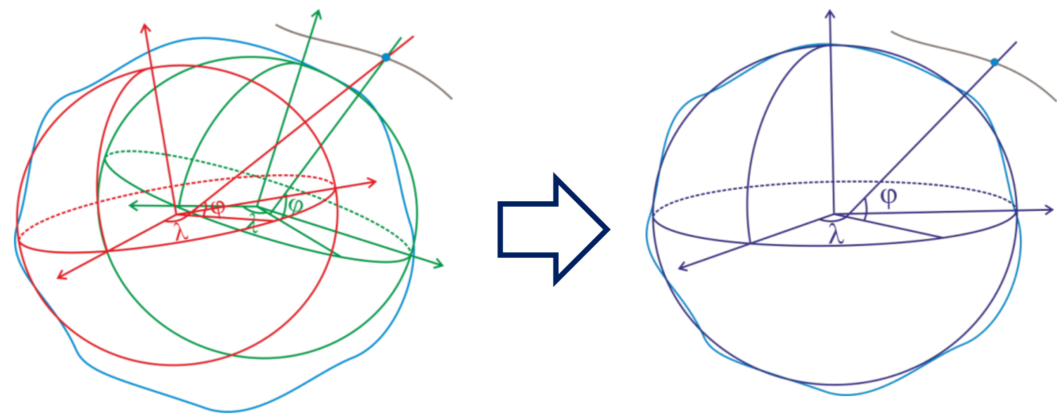


Integration of geometry, gravity field and Earth rotation, from Plag and Pearlman 2009

Existing reference systems/frames

In geometry

- **ITRS/ITRF**;
- Standardised realisation through IERS;
- worldwide unified reference frame;
- reliability in the cm-level.

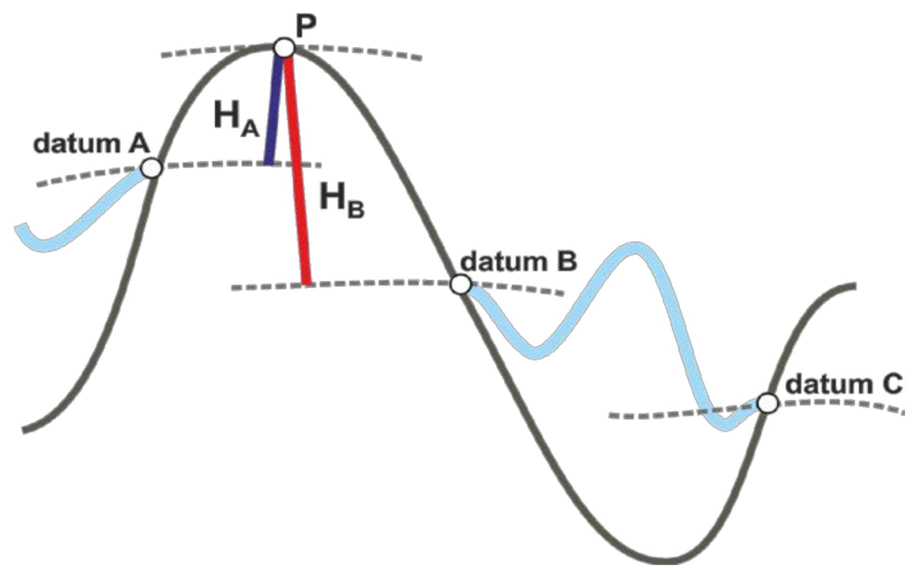


Before: many individual (local) horizontal reference systems

Today: one global unified geocentric reference system

In gravity field-related height systems

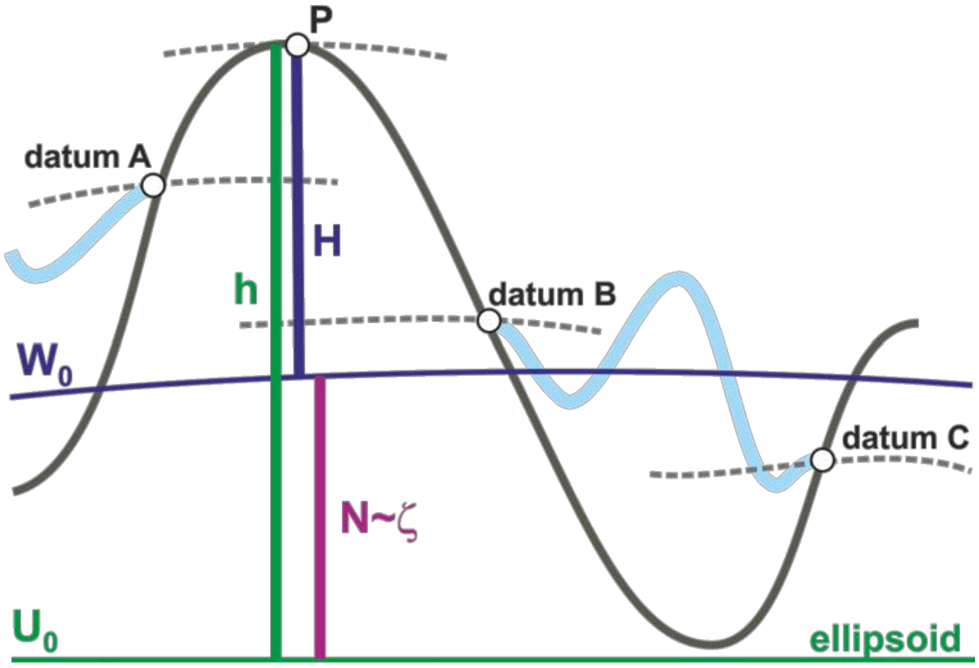
- **Different reference levels** (many [dm] of discrepancy);
- **Different types of heights** (normal, orthometric, etc.);
- Omission of (sea and land) **vertical variations** with time;
- Unprecise combination of **h-H-N**



A global vertical reference system: a GGOS challenge

Main objectives:

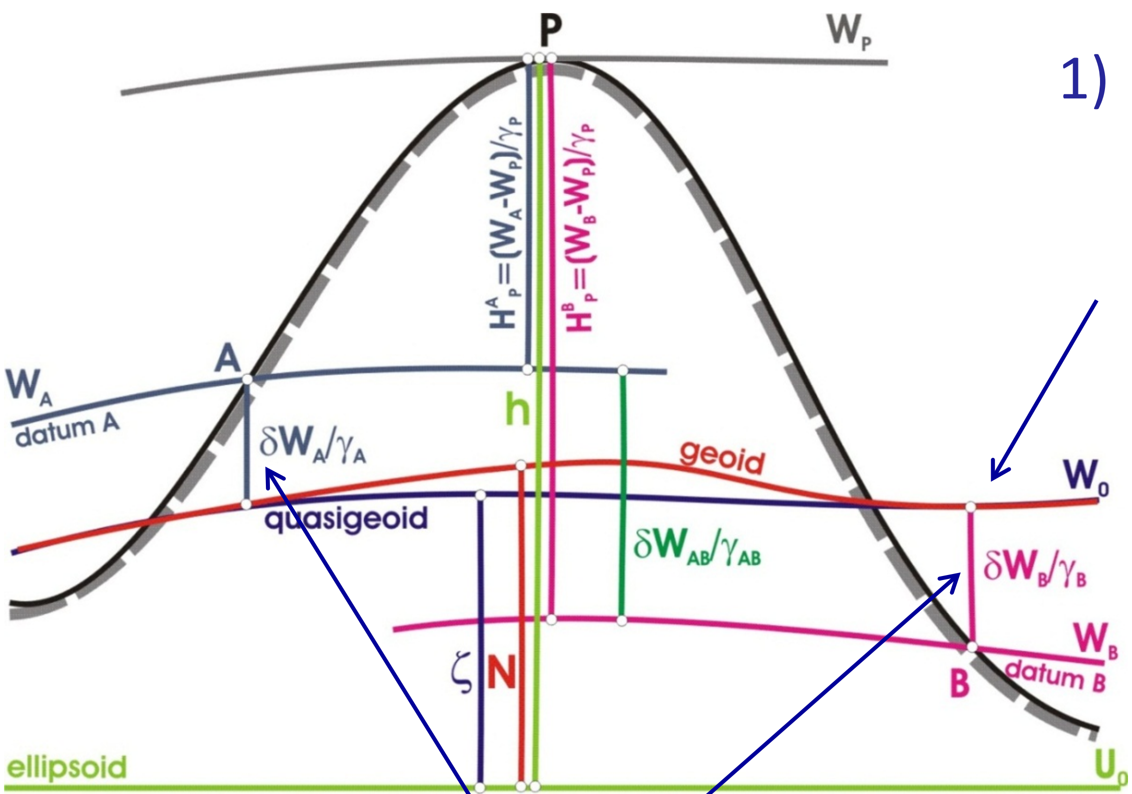
- To solve **discrepancies** between the **existing height systems**;
- To support the **different** techniques for **height determination**;
- To guarantee the same accuracy everywhere and at any time



Implicit characteristics:

- One reference level (W_0 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 $\mathbf{W_0}$
   - 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

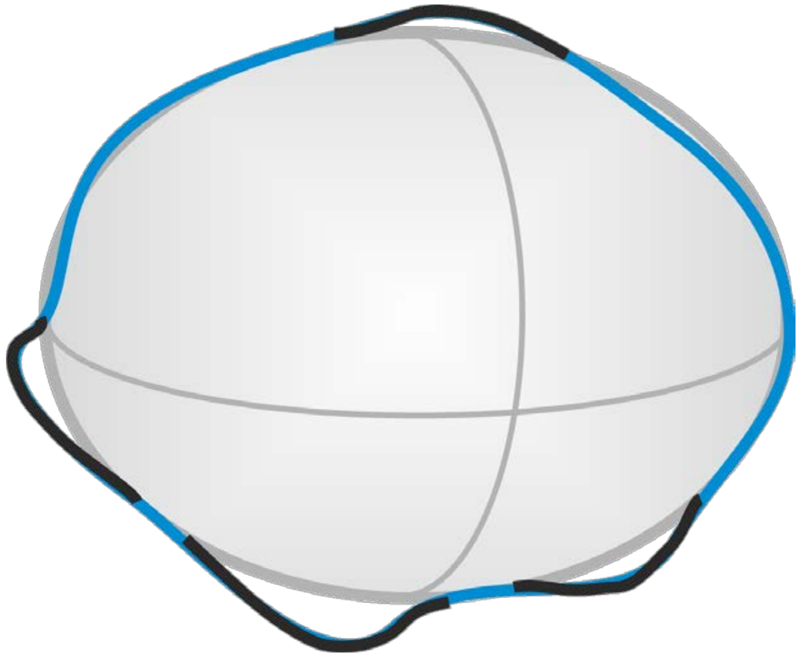
In the 1990s and before:

- 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:

$$W_0 \overset{!}{=} U_0$$



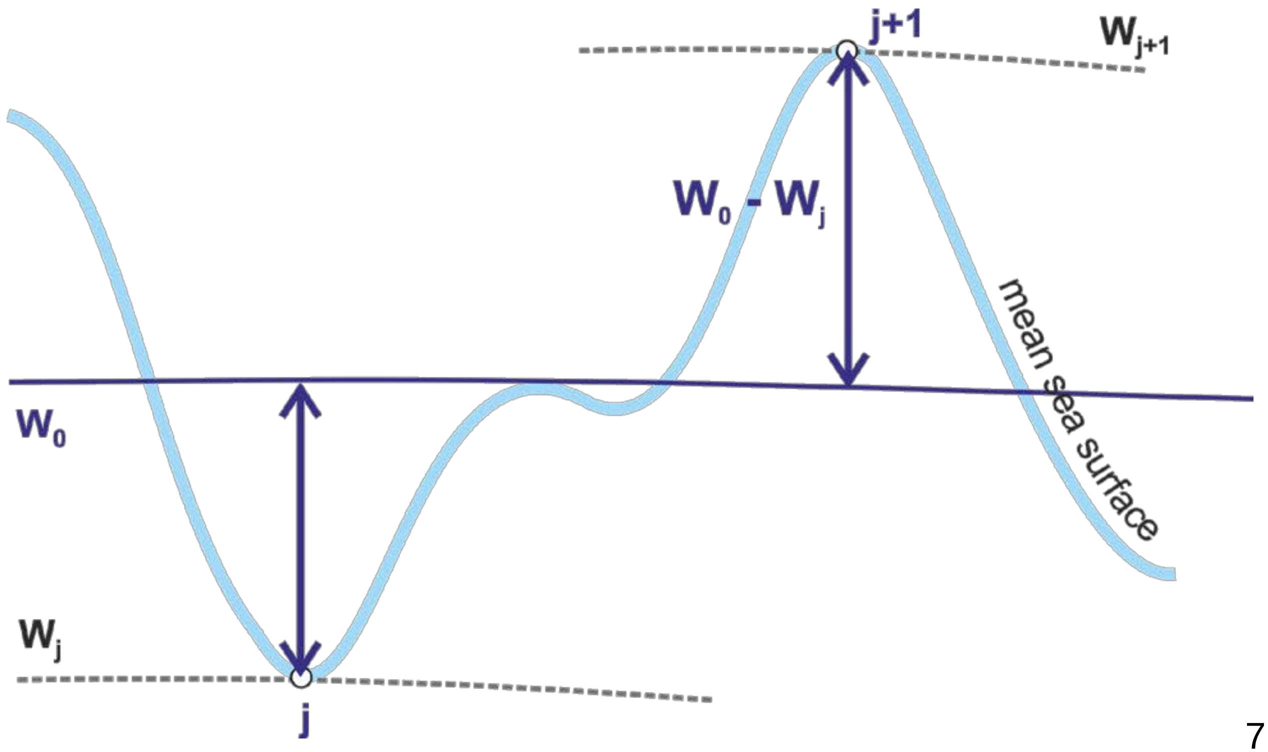
Empirical estimation of W_0

Late 1990s and 2000s:

- Points *j* with coordinates from satellite altimetry describe the mean sea surface;
- Potential values *W* are derived from a global gravity model

$$\int_S \Xi^2 ds = \min; \quad \Xi = \frac{W_0 - W_j}{\gamma_j}$$

Ξ : Sea surface topography



Empirical estimation of W_0

Today: solution of the fixed geodetic boundary value problem:

$$\nabla^2 T = 0, \text{ outside } \Sigma$$

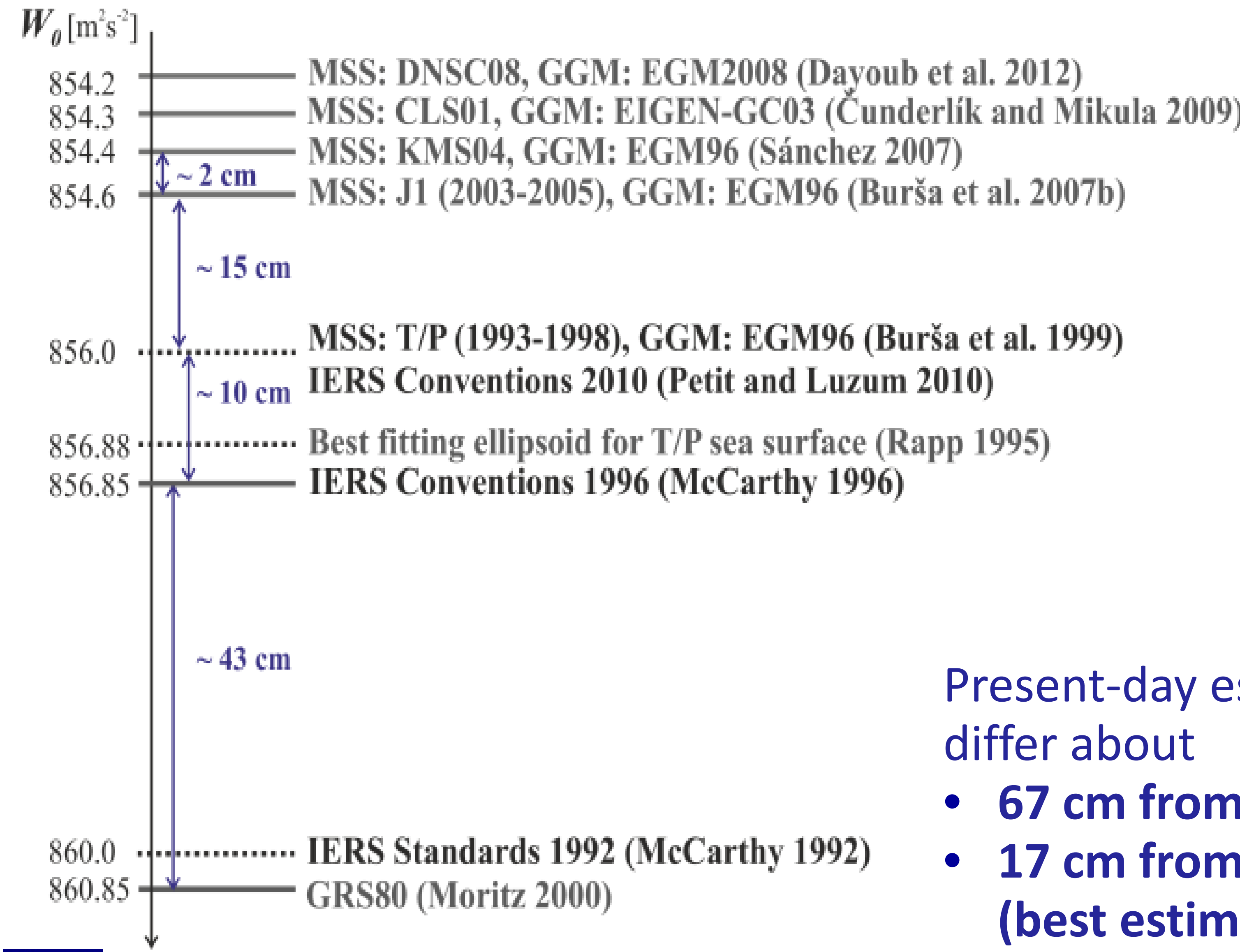
$$-\frac{\partial T}{\partial r} - \frac{2}{R} T = \delta g - \frac{2}{R} \Delta W_0^i, \text{ on } \Sigma$$

$$T \rightarrow 0, \text{ at } \infty$$

- Boundary surface Σ known;
- Unknown: datum discrepancy **ΔW** ($=W_0-U_0$)
- Boundary condition: gravity disturbances **δg**
- Regularisation: **T** vanishes at infinity

Σ ↔ sea surface from satellite altimetry, continental surfaces from SMRT
g(**X**) ↔ global gravity model
γ(**X**), U_0 ↔ GRS80

Some examples of W_0 estimates



Present-day estimations differ about

- **67 cm from GRS80 value,**
- **17 cm from IERS value (best estimate in 2004)**

WG on Vertical Datum Standardization (VDS)

Term: 2011-2015

Objectives:

- To make a recommendation about the W_0 value to be introduced as the reference level in the GGOS unified vertical reference system
- To outline the strategy for the local/regional realisation of this W_0.

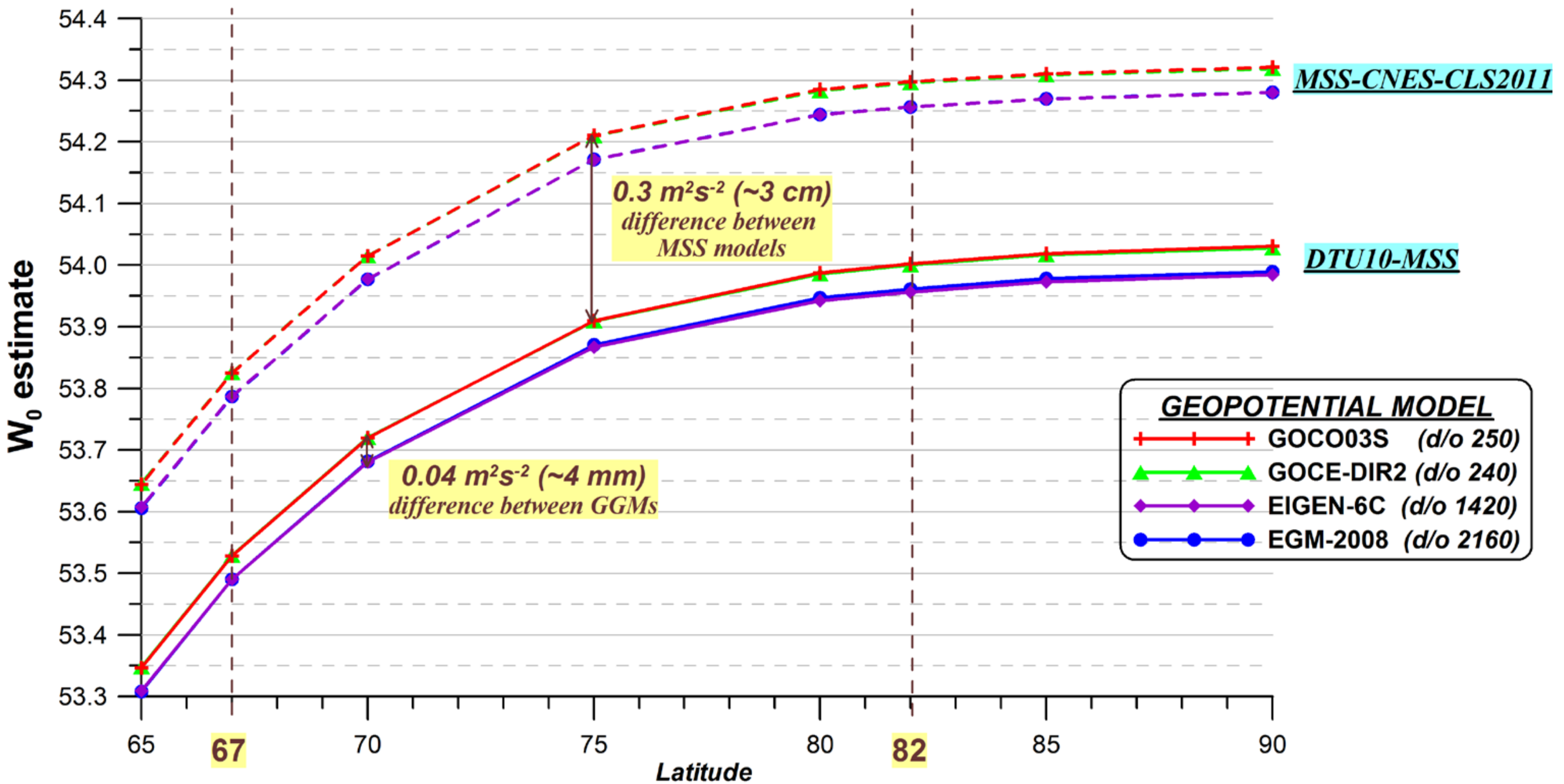
New W_0 estimations carried out within this WG

L. Sánchez (Germany)	⇨	W_0-computation based on fixed-GBVP, analytical solution
R. Čunderlík (Slovakia) Z. Faskova (Slovakia) K. Mikula (Slovakia)	⇨	W_0-computation based on fixed-GBVP, Boundary Element Method (BEM), Finite Element Method (FEM) and Finite Volume Method (FVM).
N. Dayoub (Syria) P. Moore (United Kingdom)	⇨	W_0-computation based on averaging W-values from a GGM on points describing the sea surface (MSS) W_0-computation based on a reference ellipsoid ($W_0 = U_0$)
Z. Šima (Czech Republic) V. Vatrt (Czech Republic) M. Vojtiskova (Czech Republic)	⇨	W_0-computation based on averaging W-values from a GGM on points describing the sea surface (MSS)

WG-VDS: first results

- The different teams computed W_0 using the same input data, but their own methodologies;
- It was evaluated the dependence of W_0 on:
  - Geographical coverage of the mean sea surface model;
  - Spatial resolution of the mean sea surface model;
  - Spectral resolution of the global gravity model;
  - Changes with time of the mean sea surface and the global gravity model.
- Models applied:
  - **Mean sea surface models**: MSS_CNES_CLS11 (Schaeffer et al. 2012), DTU10 (Andersen 2010), mean yearly models individually computed by (Dayoub et al. 2012, Sánchez 2012, Burša et al. 2012)
  - **Global gravity models**: EGM2008 (Pavlis et al. 2012), EIGEN-6C (Förste et al. 2011), GOCO03S (Mayer-Gürr, et al. 2012)

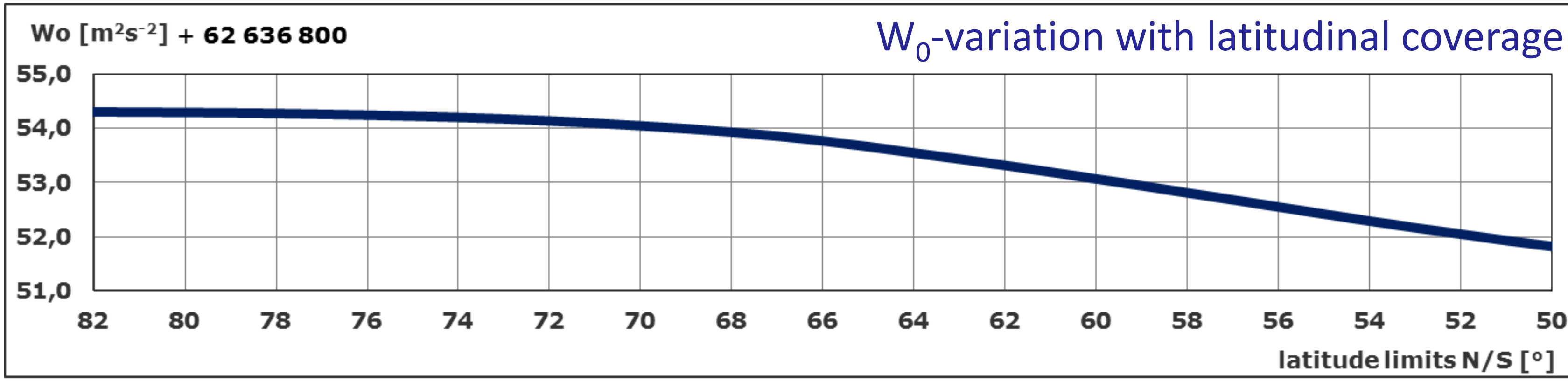
WG-VDS: some results

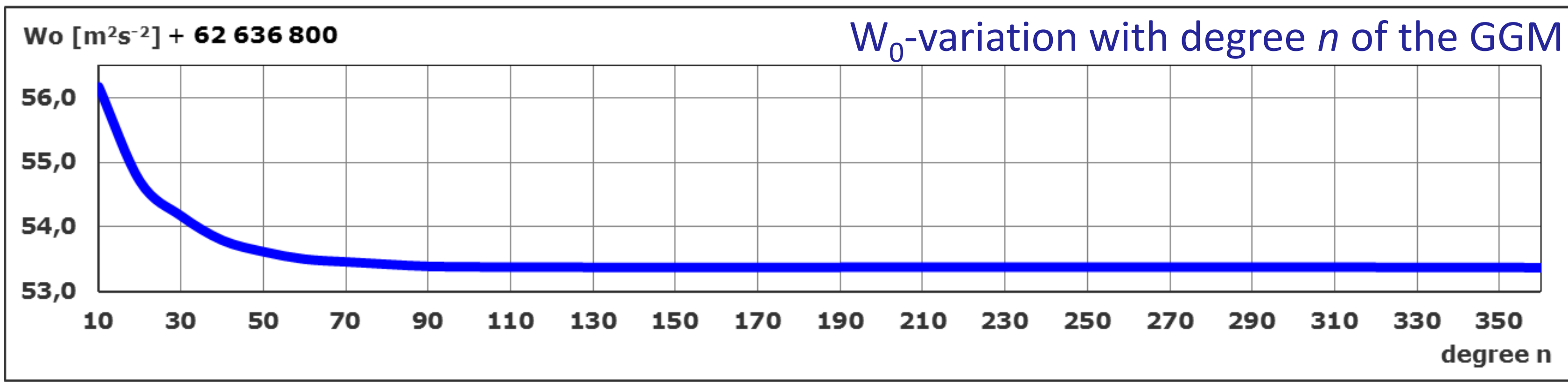


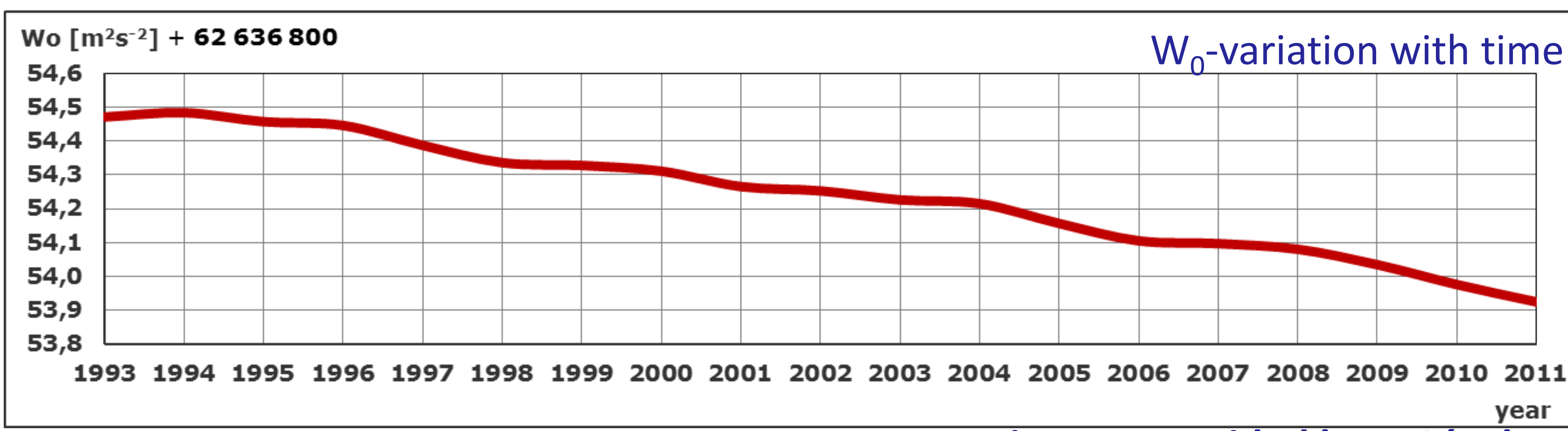
Estimates provided by R. Čunderlík, Z. Faskova, K. Mikula

WG-VDS: some results

AGU Meeting of the Americas, Cancun, Mexico, May 16 ,2013







Estimates provided by L. Sánchez

Conclusions and outlook

- All the computations are delivering very close results:
  W_0 = 62 636 854 m^2s^{-2}
- There are still minor differences (0,5 m^2s^{-2}, 5 cm), which can be solved outlining concrete standards and conventions like:
  - Latitudinal coverage 82°N/S
  - Global gravity model with n=200, derived form a combination of GRACE and GOCE data
  - Reference epoch of W_0 and its changes with time
- The computations carried out within the WG confirm that the actual in-use W_0 value (**62 636 856 m^2s^{-2}**) shall be replaced by a new (best estimate) value.
- On-going activities:
  - A formal procedure for the error propagation analysis in the W_0 computation,
  - Computation of a reference ellipsoid following the Somigliana Theory and introducing the new W_0 value as defining parameter.