A global vertical reference system in agreement with the GGOS objectives

GGOS promotes the establishment of a global gravity field-related vertical reference system to:

1) provide a global frame of reference for measuring and consistently interpreting global change processes;
2) guarantee vertical coordinates with global consistency (the same accuracy everywhere) and long-term stability (the same order of accuracy at any time);
3) support a highly-precise (at cm-level) combination of physical and geometric heights worldwide;
4) allow the reliable unification of all existing local height datums.

The global vertical reference level

The reference level of the proposed global vertical reference system is:

1) defined by a conventional $W_0$ value;
2) realised by the geometric representation of the corresponding equipotential surface with respect to a reference ellipsoid (i.e. the geoid modelling).

To ensure consistency between definition and realisation, the adopted $W_0$ value must be commensurate with measurements, models and standards used for the geoid computation. At present, the commonly accepted $W_0$ value is $62,636,856 \text{ m}^2\text{s}^{-2}$. Recent $W_0$ computations show discrepancies of about $-2 \text{ m}^2\text{s}^{-2}$ and make evident the need of a new better $W_0$ estimate.

Conventions for a new $W_0$

1) Underlying convention: the geoid is the equipotential surface coinciding with the mean sea level;
2) Empirical estimation based on the combination of global models of the Earth's gravity field and the sea surface;
3) Known effect of the secular sea level change to facilitate the integration of the existing height systems;
4) Satellite-only gravity data to avoid uncertainties caused by the terrestrial gravity data referring to the local height datums;
5) Evaluation over ocean areas only because:
   a. geometry of the sea surface is known with more accuracy than continental surfaces;
   b. geoid and quasi-geoid are the same over oceans (identical reference level for normal and orthometric heights);
   c. gravity effects of topographical features not scanned by satellite gravity are minimized (disregard of the omission error).

Strategy for the computation of $W_0$

1) Determination of the potential value of the sea surface by introducing the vanishing gravitational potential at infinity as main constraint;
2) The sea surface is given by a mean sea surface model: a set of discrete points with known coordinates derived from satellite altimetry;
3) Due to the sea surface topography ($\mathbf{\Xi}$), the points describing the sea surface are not on the same equipotential surface and a further constraint is necessary:
   \[
   \sum_{j} \mathbf{\Xi} \cdot \mathbf{\Omega} = \text{min}; \quad \mathbf{\Omega} = \mathbf{W}_0 - \mathbf{W}_f; \quad \Omega: \text{ocean surface}
   \]
4) The sea surface must be globally sampled to include all features of the sea surface topography, on the contrary, $W_0$ is not representative;
5) Since the mean sea level coincides with a different equipotential surface depending on the time span used for averaging sea surface heights, a certain epoch shall be selected.

Working Group on Vertical Datum Standardisation

In order to make a new best estimate for the $W_0$ value available, the Working Group on Vertical Datum Standardisation was established for the term 2011-2015 with the following main objectives:

1) to identify the basic conventions needed to guarantee uniqueness, reliability and repeatability of the $W_0$ estimate;
2) to release a recommendation about the $W_0$ value to be introduced as the reference level in the GGOS vertical reference system;
3) to outline a strategy for the local/regionalealisation of the reference level defined by the new $W_0$.

Dependence of the $W_0$ estimate on the mean sea surface model

1) When the latitude coverage is reduced, features of the sea surface topography are excluded and $W_0$ decreases, i.e. it is not global.
2) By using the models MSS-CNES-CLS11 and DTU10 there is a difference of $0.31 \text{ m}^2\text{s}^{-2}$, which reflects the mean discrepancy of $\sim 3 \text{ cm}$ between both models. Possible causes:
   a. Different strategies to process the altimetry data;
   b. Different reductions taken into account in each model;
   c. Different periods (inter-annual ocean variability).
3) Alternative: use of yearly mean sea surface models:
   a. the $W_0$ estimates reflect (with opposite sign) the sea level rise measured by satellite altimetry;
   b. a reference epoch shall be adopted.

Dependence of the $W_0$ estimate on the choice of the gravity model

1) Models including GRACE, GOCE and Satellite Laser Ranging data are preferred. Recent models provide differences $< 0.01 \text{ m}^2\text{s}^{-2}$.
2) The use of a satellite-only gravity model is suitable. After $n = 200$ the largest differences are $0.001 \text{ m}^2\text{s}^{-2}$, which are negligible.