Towards a vertical datum standardisation based on a joint analysis of TIGA, satellite altimetry and gravity field modelling products

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Introduction: Classical height systems

→ Reference level realised by the mean sea level at individual tide gauges over different time periods.

→ Vertical coordinates from spirit levelling with gravity reductions (e.g. orthometric with different hypotheses).

→ There are as many height systems as reference tide gauges (and applied orthometric hypotheses).

→ Reference levels and heights relate to different epochs, not considering vertical crust and sea level changes.

→ Relative precision is high (mm-level); absolute accuracy (m-level) is insufficient for global change research.

→ Combination of levelled heights (H) with GNSS heights (h) and geoid models (N) is unrealistic (at m-level).

Vertical datum standardisation in practice

Determination of datum discrepancies (δW_i, δW_j, Fig. 1) between gobal (W_0) and local (W_i, W_j ...) levels by

→ Establishing a global vertical frame including reference tide gauges, main levelling points (nodes) and ITRF (SIRGAS, EPN, …) stations.

→ Connecting levelling networks between neighbouring countries (or datum zones).

→ Combining ellipsoidal heights (space techniques), geopotential numbers (levelling and gravity), and solutions of the boundary value problem based on terrestrial and satellite gravity at the fundamental stations of the global vertical reference frame.

Vertical datum analysis based on the TIGA products

→ To refer tide gauge benchmarks to the geocentric reference system (ITRS/ITRF) and determine the vertical displacement trend (constant velocity) of the Earth crust at their locations.

→ To estimate sea level trends at each reference tide gauge from their historical registrations.

→ To determine sea surface secular variations in the marine areas surrounding the analysed tide gauges from satellite altimetry measurements.

→ To reduce the different mean sea levels (used for the height datums) for vertical crustal movements by combininig these three items.

→ To reduce the estimated δW_i discrepancies to the same epoch of the zero-height realisations.

Objectives of a vertical datum standardisation

→ To provide a highly precise physical reference frame (consistent at sub-cm level beyond national borders) equivalent to the geometrical one, i.e. ITRF and its regional densifications like SIRGAS, EUREF-EPN, etc.

→ To support determination and combination of geometric (h) and physical heights (H).

→ To satisfy h-H-N=0 at the cm-level in a global frame.

→ To establish a similar realisation to ITRS/ITRF, i.e.
- a global network with known vertical coordinates;
- regional and national densifications of the global network by integrating (transforming) the existing height systems.

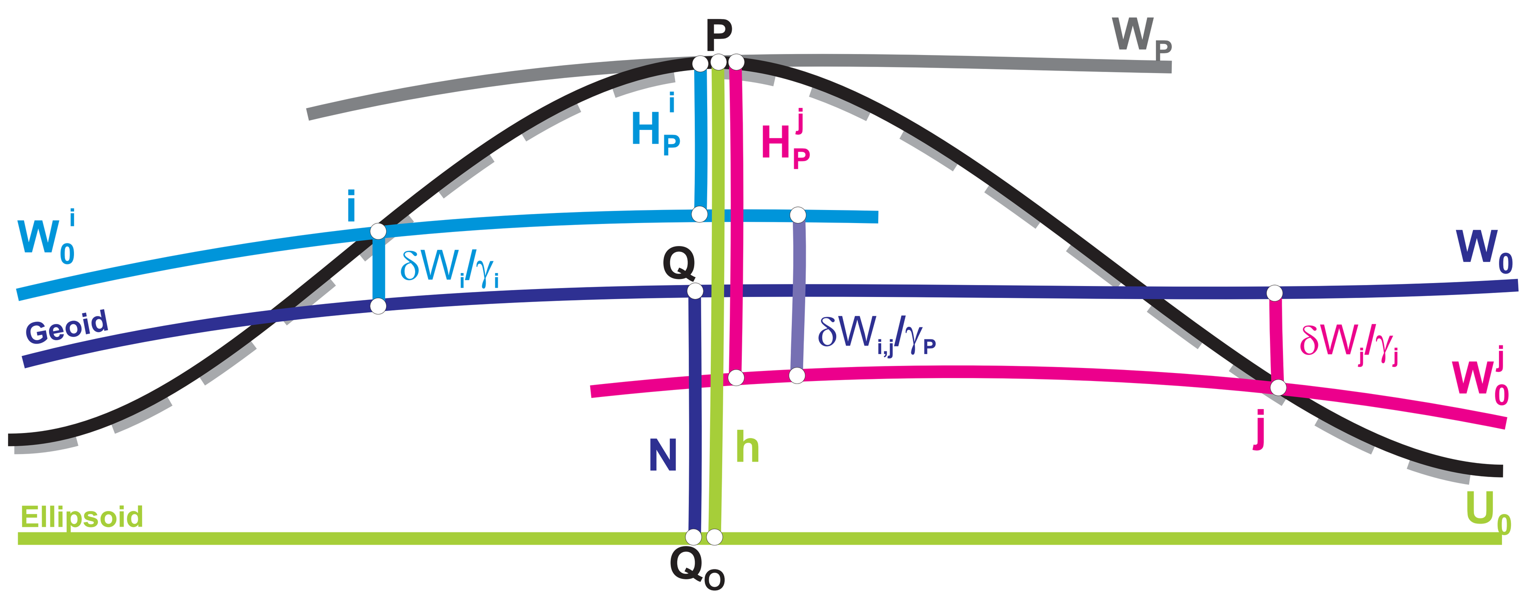
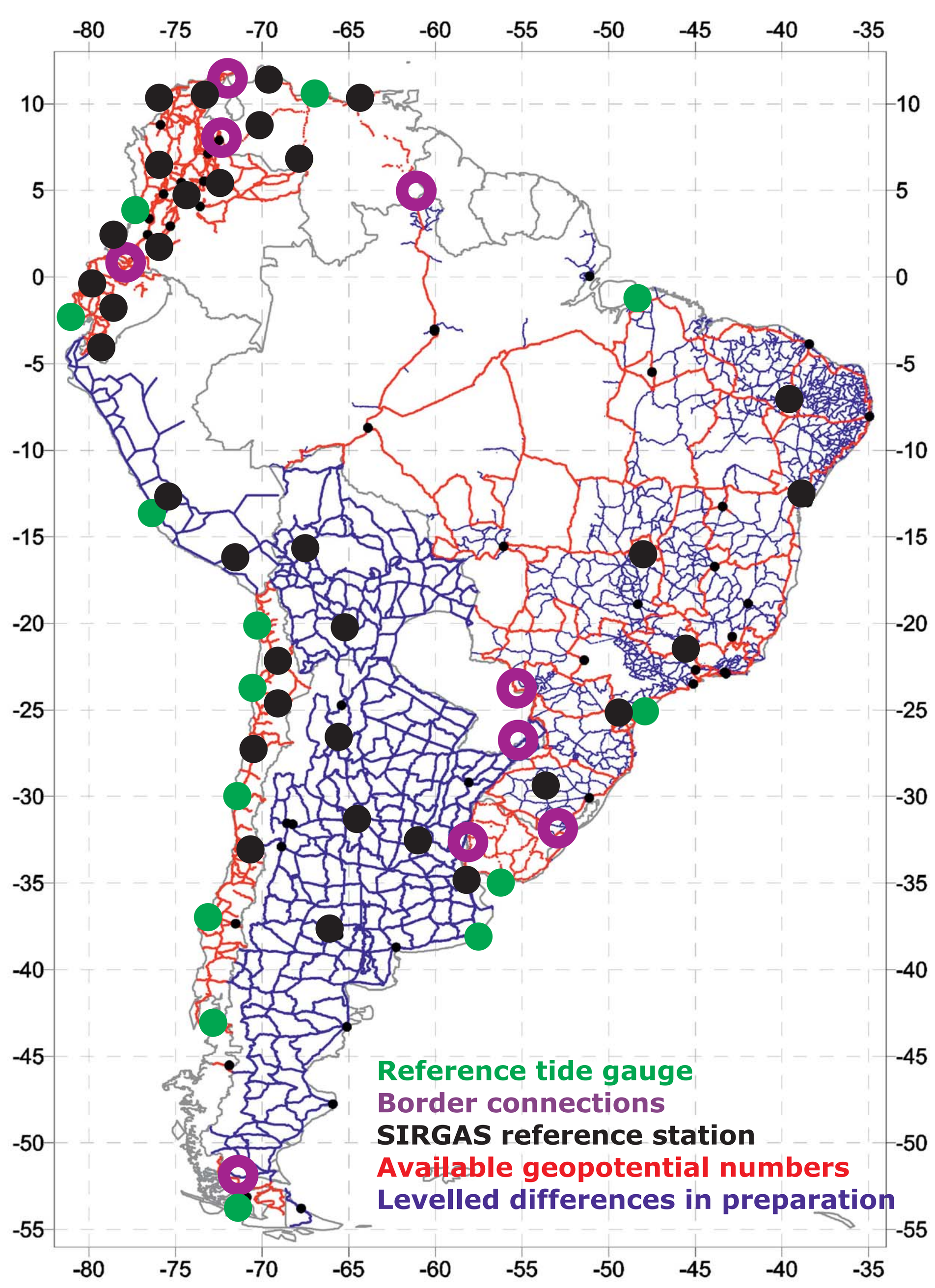


Fig. 1. Relationship between classical height datums (i, j, ...) and a global vertical reference level W_0.

Example: South America (preliminary)



Observation equations

→ 14 reference tide gauges

$$\delta W_i = \gamma\, h_{Sat.Alt+TG} - T_{GGM}$$
$$\delta W_i^{TG} = \gamma\, h_{SIRGAS} - T_{GGM+Terr.Data}$$

→ 37 SIRGAS reference stations

$$\delta W_i^{SIRGAS\ stations} = \gamma\, h_{SIRGAS} - C_i - T_{GGM+Terr.Data}$$

→ 8 connections between neighbouring countries

$$\delta W_{ij} = C_j - C_i$$

Adjustment

→ Unknowns: 15 vertical datums (14 tide gauges + Paraguay)

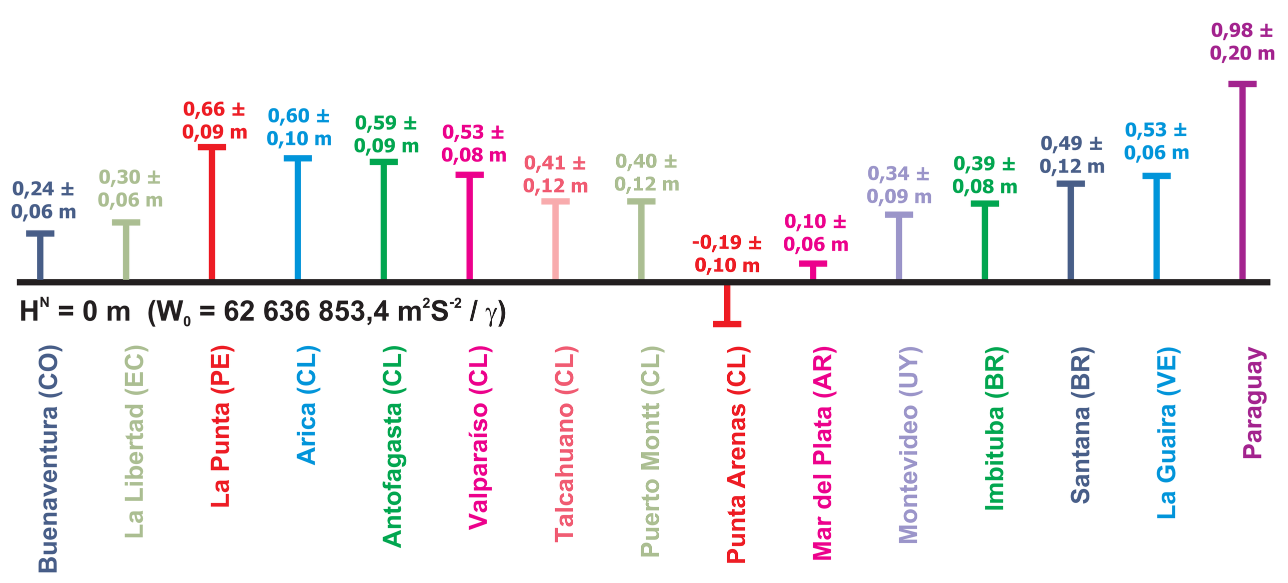
→ Observation equations: 73

→ Adjusted values:

$$\delta W_i^* = \left[A^T PA\right]^{-1}\left[A^T P\delta H_i\right]$$

Results (accuracy at dm-level)

→ Largest uncertainty: Paraguay (no tide gauge, no SIRGAS station).



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