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 (ΔW₀, ΔWᵢ, Fig. 1) between global (W₀) and local (Wᵢ, Wᵢ,...) 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 combining these three items.
→ To reduce the estimated ΔWᵢ discrepancies to the same epoch of the zero-height realisations.

Example: South America (preliminary)

Observation equations

→ 14 reference tide gauges
  \[ ΔWᵢ = γ (hᵢ - Hᵢ - Tᵢ CGM) \]
  \[ ΔWᵢ CGM ≈ γ (hᵢ - Hᵢ - Tᵢ CGM + TT) \]

→ 37 SIRGAS reference stations
  \[ ΔWᵢ SIRGAS ≈ γ (hᵢ SIRGAS - Cᵢ - Tᵢ CGM + TT) \]

→ 8 connections between neighbouring countries
  \[ ΔWᵢ = Cᵢ - Cᵢ \]

Adjustment

→ Unknowns: 15 vertical datums (14 tide gauges + Paraguay)
→ Observation equations: 73
→ Adjusted values:
  \[ ΔWᵢ = \left[ \begin{array}{c} A \end{array} \right] \left[ \begin{array}{c} ΔF \end{array} \right] \]

Results (accuracy at dm-level)

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

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