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LATEST ADJUSTMENT OF THE ARGENTINE HEIGHT SYSTEM

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1. Abstract

For over 70 years, the National Geographic Institute of Argentina (NGI) has undertaken a systematic project to build benchmarks throughout the country, which have been measured with spirit leveling and gravimetric techniques.
The first adjustment of this network took place in 1971. This assignment was given to the Defense Mapping Agency of the United States of America (DMA). Leveling lines that were built and measured after the year 1971 were adjusted to this original network. A new adjustment calculation with modern techniques was needed to update the entire network.
All historical field books were digitalized to retrieve the information corresponding to the spirit leveling, from which it was then possible to calculate geopotential difference between the nodes, using gravity acceleration values over the benchmarks.Subsequently, by the method of least squares it was possible to calculate the geopotential numbers of the nodes, and then the orthometric height of all the benchmarks. The recommendations of the Working Group III of SIRGAS (Geodetic Reference System for the Americas) were taken into account in relation to this task.
The development of this paper shows the results that have been obtained so far in the development of the New Height System for Argentina.

2. High Precision Leveling Network

The national altimetric network is referred to the mean sea level determined by Mar del Plata's tide gauge (1923). It is composed of approximately 18,000 benchmarks, in which 82% have gravity acceleration values.
The high precision leveling lines divide the Argentine territory into 158 closed polygons. The network develops along roads. That is the reason for the irregular tracing of polygons (Figure 1).

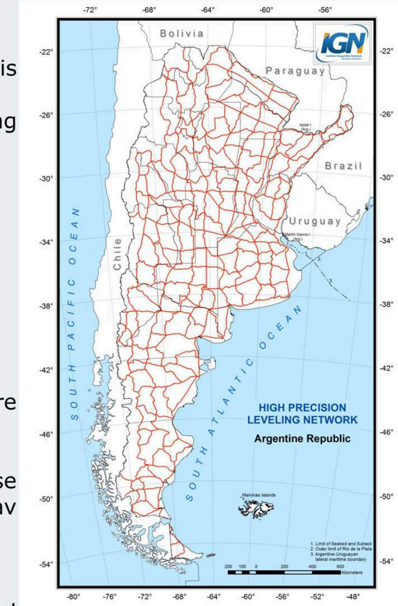


Figure 1

3. Methodology

The following methodology was applied to obtain the new orthometric height values of the benchmarks:

I. Digitalization
The first step was to digitalize the historical field books to retrieve the spirit leveling information.
II. Geometric heights calculation
Secondly, the geometric closures of all the polygons that compose the High Precision Leveling Network were calculated (Figure 2).
III. Geopotencial heights calculation
Subsequently, geopotential heights were calculated from measured gravity values over the benchmarks. For those benchmarks that have not been measured with gravimeters, the acceleration values were estimated using PredGrav (H.Drewes) software, provided by SIRGAS.
Then, the closure of the polygons was undertaken in terms of geopotential height differences (Figure 3).
IV. Detection of gross errors
After calculating the geopotencial height differences it was possible to analyze the closure of all the polygons, and exclude leveling lines affected by measurement gross errors in relation to the future adjustment (Figure 4).
V. Adjustment
The least squares method was applied to adjust the leveling network. The matrices were built up using geopotential differences between nodes.
The geopotential Datum was established at Mar del Plata's Tide Gauge.
The values of the Weight Matrix was established by the formula Pi=1/Li[m]
After calculating the adjusted geopotential numbers of the nodes, it was possible to compute the geopotential numbers of all the benchmarks between the nodes.
VI. Orthometric heights computation
Finally it was possible to derive the geopotencial numbers of all the benchmarks to orthometric heights using the following methods: Free-Air Reduction, Remove-Restore Bouguer Reduction, and Hammer Topographic Correction (see B and C).

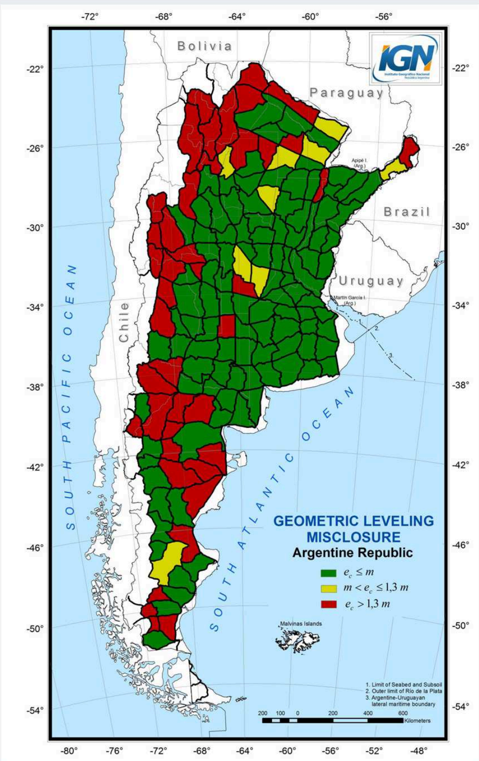


Figure 2

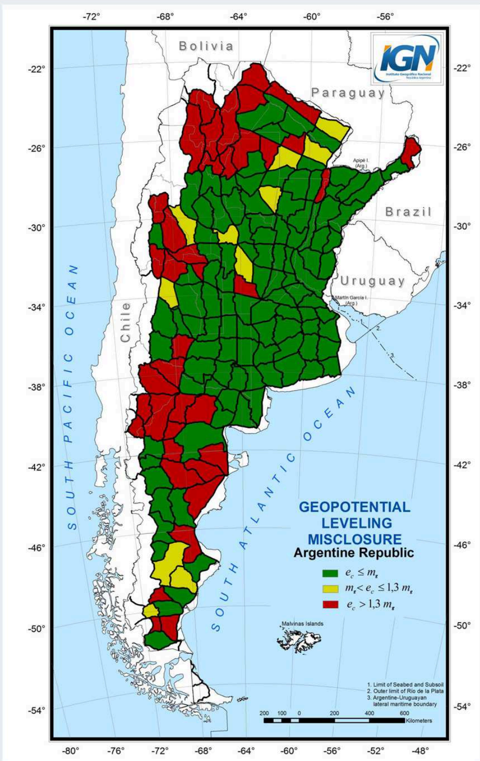


Figure 3

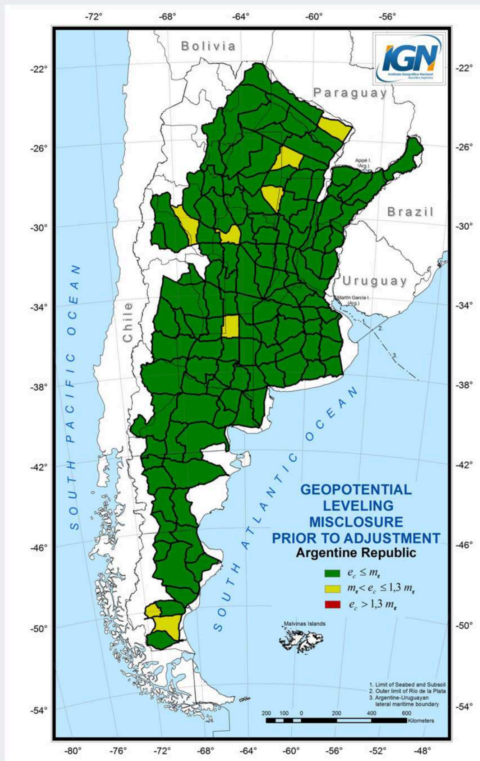


Figure 4

4. RESULTS

The Sigma value after the adjustment was 0.027.
Figures 5 and 6 show the difference between the current and the latest adjustment of the network calculated over the nodes.

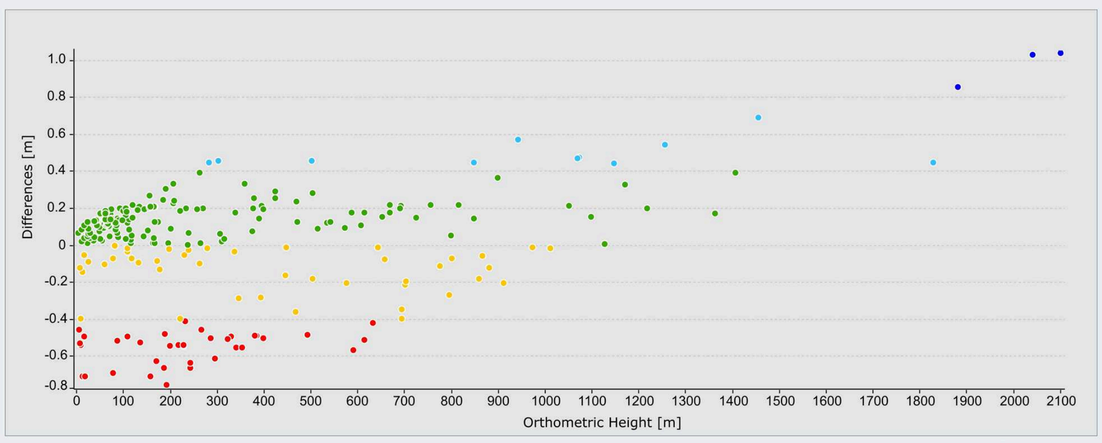


Figure 5

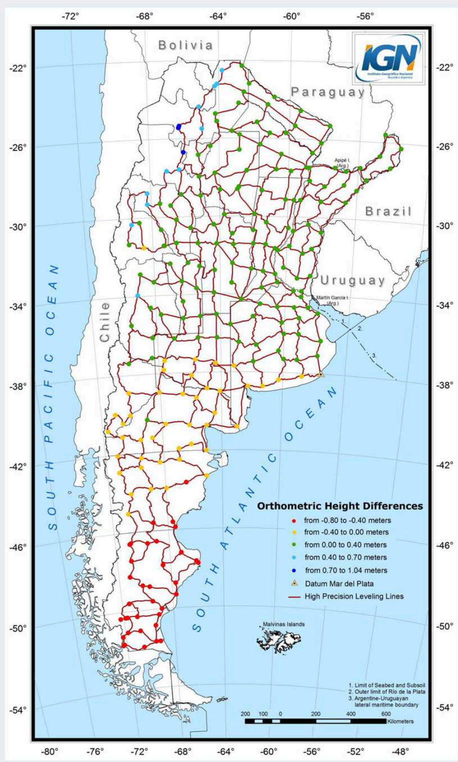


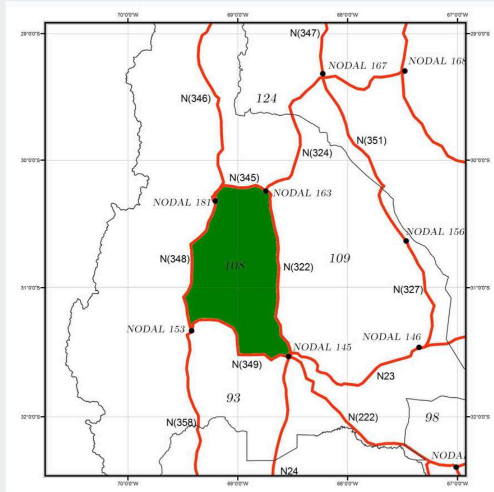
Figure 6

5. FINAL COMMENTS

Topographic Correction has been an important step for the calculation of Orthometric Heigths. In mountain regions, this correction reached 50 mgal.
Our objective is to undertake a new adjustment taking into account rock density variations.

A. Leveling circuit example

The following map shows an example of a leveling circuit:



Leveling Line	ΔH Geom. [m]	ΔH Orth. [m]	Δ Poten. [m^2/s^2]	Distance [m]
N(349)	-719.059	-719.094	-7039.926	131684
N(322)	526.913	526.952	5158.762	158985
N(345)	659.421	659.329	6454.702	60172
N(348)	-467.176	-467.195	-4573.026	134824
Σ ΔH	0.099	-0.008	0.512	485665
Tolerance	0.066			

The accuracy established for high precision leveling lines is:

$$m = 3[mm] \times \sqrt{L[km]}$$

m: Tolerance
L: Length of line

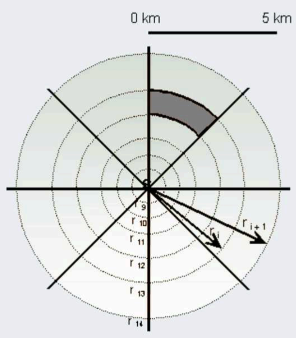
B. Gravity Reductions

- Remove Bouger Plate: $-0.1119 \times H[mgal]$
- Free-Air Reduction: $+0.3086 \times H[mgal]$
- Restore Bouger Plate: $-0.1119 \times H[mgal]$
- Topographic Correction (Hammer Chart):

$$\delta g_t = \sum \rho \frac{2\pi}{n} G\left(r_{i+1} - r_i + \sqrt{r_i^2 + \Delta h_i^2} - \sqrt{r_{i+1}^2 + \Delta h_i^2}\right)$$

The SRTM v4 model was used to implement topographic correction. Used parameters:

$$\rho = 2.67\ gr/cm^3, \quad \alpha = 2\pi/n \quad (n = 360° \ or\ \alpha = 1°),$$
$$G = 6.67428 \times 10^{-11}\ m^3 kg^{-1} s^{-2}, \quad r = 100\ m,$$
$$\text{maximum distance} = 160\ \text{km}$$


Hammer Chart

C. The Orthometric Height

$$H^0 = \frac{C}{\bar{g}}$$
$$C = \int_0^H g \cdot dH$$
$$\bar{g} = \frac{1}{H}\int_0^H g \cdot dH$$

H: Orthometric Heigth
C: Geopotential Number
$\bar{g}$: Mean Gravity along the plumbline
g: Surface Gravity measurements

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