Guidelines for performing gravimetric measurements around IHRF stations

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This document has been structured on the basis of the bibliographic references cited in the "References" section. The guidelines have been prepared by SIRGAS Working Group III: Vertical Datum. SIRGAS appreciates the collaboration of its colleagues who have contributed their comments and suggestions.

In order to keep this document up-to-date, you are cordially invited to send your comments, questions or suggestions to the president of SIRGAS Working Group III (GT-III).

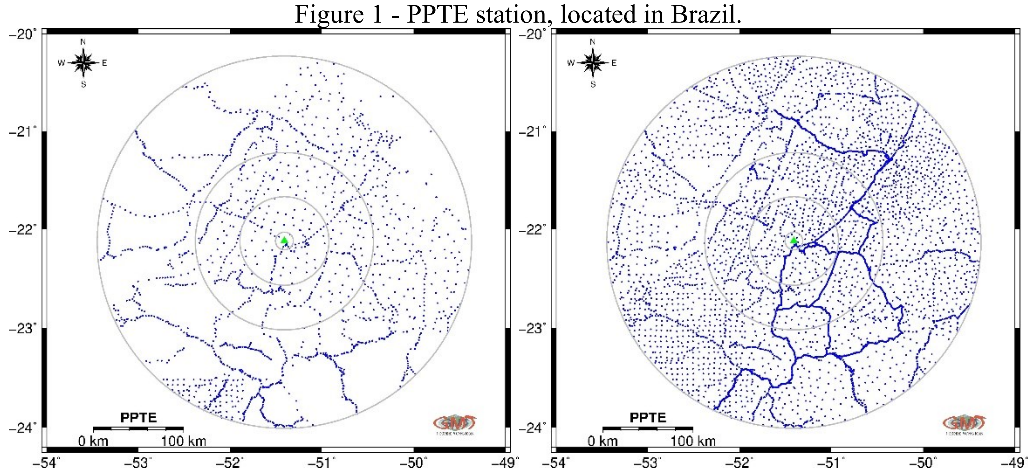
This document describes the relevant requirements and recommendations for performing ground gravimetric measurements around IHRF stations (International Height Reference Frame). The following guidelines are aimed at institutions that already have a station planned in the calculation of the first IHRS implementation (International Height Reference System), and at those wishing to implement it. For details on the selection and implementation of an IHRF station, please see the technical guide "Instructions for the selection of IHRF stations" available at https://sirgas.ipgh.org/en/resources/guidelines/.

1. General Information

To achieve the desired precision in potential values (W(P)) at IHRF stations, the distribution and quality of the gravimetric measurements are essential. In accordance with the guidelines and recommendations given in the Focus Area "Unified Height System" of the Global Geodetic Observing System (GGOS) and Working Group 0.1.2: "Strategy for the realization of the IHRS" (Sánchez 2019; Sánchez; Barzaghi 2020, Sánchez et al., 2021), the main requirements and points to be highlighted are as follows:

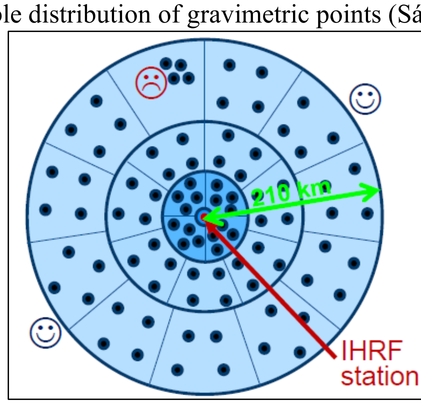
a) Filling the gravimetric voids around the IHRF reference station is the first fundamental point. Figure 1 illustrates the gravity voids (zones without gravimetric measurements) at the PPTE station in Brazil (figure on the left) and the filling of these voids (figure on the right).

Figure 1 - PPTE station, located in Brazil.



b) The distribution of the gravimetric points must be homogeneous, with measurements lying in a radius of 210 km (~2º) around the IHRF station. Figure 2 shows the approximate distribution, without taking into account the ideal number of stations.

Figure 2 - Desirable distribution of gravimetric points (Sánchez et al., 2017).



c) The spatial resolution recommended by the IAG 0.1.2 Working Group for gravimetric measurements is 2 to 4 km, depending on the relief. In mountainous areas, gravimetric observations should have a better resolution than in flat areas. Relative measurements are known to be expensive and time-consuming activities. Therefore, if it is not possible to comply with the recommendation for the ideal quantity, an attempt should be made to establish measurements with a spatial resolution of a maximum of 9 km (which should be higher in mountainous areas or those with a greater topographical variation). It is clear that the better the spatial resolution of the points, the better the precision of the potential values obtained for the IHRF station. On the other hand, in remote areas where there are no roads or paths, such as forests and deserts, as well as in the mountains, the use of aero-gravimetry is suggested for geodetic purposes.

d) In the case of the existence of gravimetric data, the quality of the information must be verified, especially the quality of the GNSS height and possible systematic errors. To minimize low-grade systematic errors in existing data sets, it is necessary to verify the link of the densification data to the gravimetric reference from absolute gravity measurements.

e) In the case of new gravimetric measurements, these must be connected to modern and reliable gravimetric reference networks. Absolute gravity observations should preferably follow the recommendations given in the new International Gravity Reference Frame (IGRF) (Wziontek et al. 2021). Accompanied by gravimetric measurement, the coordinates (φ, λ, h) must be determined with GNSS receivers. It should be noted that the pieces of equipment (GNSS receiver and gravimeter) should be placed near each other and in the same plane as shown in Figure 3.

Figure 3 - Gravimetric survey accompanied by GNSS measurement.

f) The recommended accuracy for the gravity acceleration value is ±0.15 mGal (a value of up to ±0.5 mGal is acceptable); and for the coordinates, something better than ±0.3 m for height and ±1.0 m for the horizontal component (Denker, 2013).

2. Gravimetric measurements

In this guide, the following definitions are adopted:

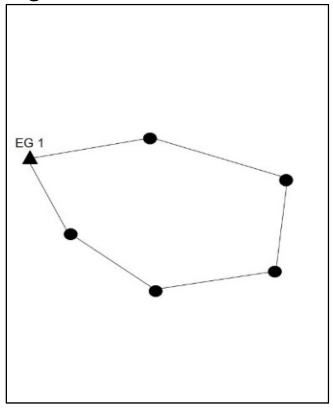
- Absolute gravity reference: made up of stations materialized and established with absolute gravimeters and which are linked, preferably, to the new IGRF. The term “**reference**" rather than "**net**” should be used as these are measurements made with absolute gravimeters.

- First order network: established using materialized stations and measured with relative gravimeters. They must be linked to the absolute gravity reference and meet specific precision criteria as regards their establishment.

If new gravimetric measurements are made around the IHRF stations, the following aspects should be observed:

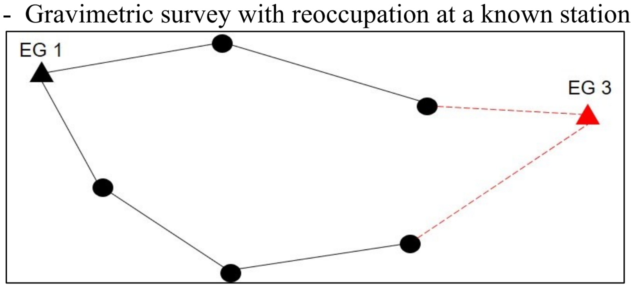
a) It is recommended that before any gravimetric campaign is held, field planning should be carried out, as well as the verification and calibration of the equipment to be used, according to the specificity of each device. In addition, it is advisable to check and adjust, when necessary, the sensitivity of the equipment at the start of each survey. This technical guide does not address the operation of gravimetric equipment. For this, the “References” section presents some bibliographic suggestions and technical manuals.
b) The gravimetric densification stations should be linked to the first order reference stations whenever possible, or to the second order network. It is not necessary for these densifications to be materialized by the stations.
c) The orientation is such that the gravimetric circuits destined for densification are of the "closed" type, meaning when the survey begins and ends at the same base station. (Figure 4).

Figure 4 - Gravimetric circuit.



d) Reoccupations should be carried out whenever possible in first or second order stations, or even in densified stations suitable for reoccupation, which must be located close to the work area (Figure 5). This allows there to be adequate control of the observations, in addition to detecting possible inconsistencies of the gravimeter.

Figure 5 - Gravimetric survey with reoccupation at a known station (in red).



e) Depending on the type of gravimeter used, the following readings procedures are recommended:

- Mechanical optical gravimeter: Three readings to be taken within a maximum interval of 3-5 minutes. The maximum discrepancy between the readings should not exceed 0.005 graduation units.

- Digital gravimeter: Three reading cycles, each cycle of 2 minutes. The maximum discrepancy between the readings should not exceed 0.01 graduation units.

After collecting the information in the field, the next step is to process the data. In this case, there are no SIRGAS recommendations regarding the software to be used for processing, as the choice of the computer program is the responsibility of the institution.

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