A new compilation of gravity data over the Iberian Peninsula and surrounding areas

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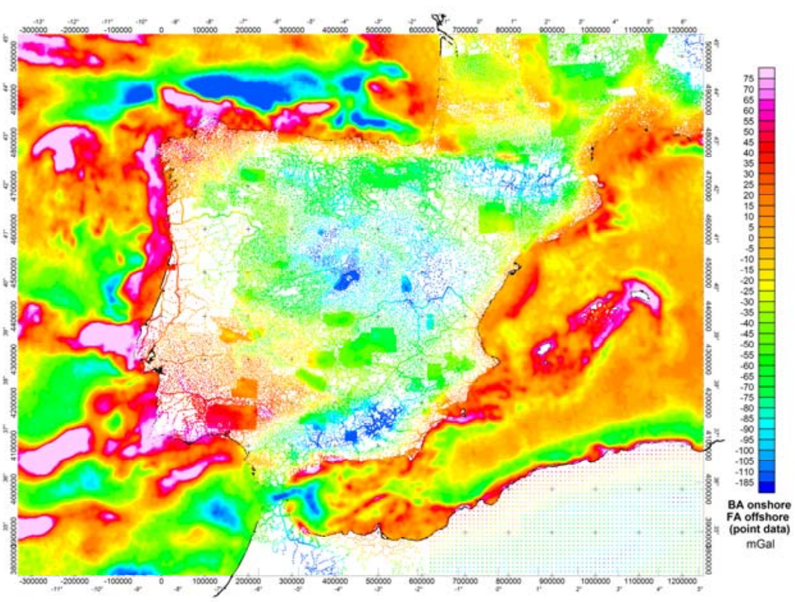

CONTRIBUTORS

Several Institutions have contributed with original gravity data onland (in alphabetical order):

Bureau Gravimetrique International (BGI)
Instituto Geológico y Minero de España (IGME)
Universidad de Granada (UGR)
Universidad de Oviedo (UniOvi)

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SUMMARY

The aim of this work is the compilation of available gravity data over the Iberian Peninsula following strict quality control procedures to improve the spatial resolution compared to previous compilations and its publication on the Internet to ensure its public availability. Until the Inspire directive provides a European standard for the gravity databases, it is used the structure of the Bureau Gravimetric International (BGI) gravity database as a template. Additionally, the importance of establishing a common database standard is discussed because, on one hand, it will allow the users to assess the quality of the gravity data together with its limitations regarding the analysis and interpretation of the gravity anomalies and, on the other hand, it will facilitate the incorporation of new data into the database. Finally, a study of the spatial resolution of the data and the appropriated grid spacing for the whole Peninsula is presented.

INTRODUCTION

The story of gravity data acquisition in the Iberian Peninsula goes back as far as 1877 (see http://www.ign.es/ign/layoutIn/gravimetriaPeriodo1.do, Inglada, 1923, Mezcua et al, 1996 and Álvarez 2002 for more historical information). One of the most relevant historical benchmarks on the gravimetric cartography occurred in 1973, when the National Geographical Institute established the Fundamental Gravimetric Network, which was linked with the IGSN1971. From that date on, the acquisition of gravimetric data increases and in 1978 the free air and Bouguer anomaly maps, based on 2621 stations, were presented (San Millán, 1978). In Catalonia, new observations were carried out, up to a total of 2366 stations, from where the free air and Bouguer anomaly maps were obtained at 1:500000 scale (Casas et al., 1986 and Torné et al., 1988). For the first time, topographic correction up to 167 km was applied, which was an important innovation respect to previous surveys in Spain. The anomalies were calculated using the GRS67 formulas.

A gravimetric cartography for the entire Iberian Peninsula with topographic correction was carried out in 1992, when a 200 m DTM was made available for the whole territory. Thus, the first free air and Bouguer anomaly map covering the Iberian Peninsula and the Balearic Islands with stations topographically corrected up to 167 km was obtained and published in 1996 by the National Geographical Institute (Mezcua et al., 1996). 32976 stations were used and the calculations were made in the GRS80 Geodetic Reference System (Moritz, 1984).

In the late nineties and the early years of the twenty first century, a thorough compilation of gravity data was carried out at IGME (Manuel Olmo, pers. com.) A total of 119200 stations from 393 different surveys were revised and standardised using the GRS67 Geodetic Reference System, a density reduction of 2600 kg/m^3 and a topographic correction at least up to 22 km. The resulting database was made available to the public through a web based interface called SIGEOF (http://www.igme.es/internet/sigeof/inicio_eng.html) that has recently become part of the web portal SIGECO, that allow free access to the public geological and geophysical data held at IGME (http://cuarzo.igme.es/sigeco/default.htm).

A Spanish law from 2007 (BOE-A-2007-15822) establish that from January 1st 2015 onwards, the only geodetic reference system to be used in any cartography must be the ETRS89 (European Terrestrial Reference System 1989). This geodetic system has associated the reference ellipsoid GRS80 which in turn has associated a body of gravimetric formulae, described in detail by Hinze et al. (2005). A tentative proposal to revise and update the gravimetric IGME database to meet the requirements described in this REAL DECRETO 1071/2007 and consequently, incorporating the new standards proposed by Hinze et al. (2005), was made by IGME in 2009 (Rubio and Ayala, 2009), where a thorough revision of the Bouguer anomaly formulae was made. At the end, it was decided that the new data acquired by IGME was to be calculated in GRS67 to comply with the actual IGME database and in GRS80, to meet the new standards.

In recent years, several gravimetric compilations have been made, being the latest the one made by Gomez-Ortiz et al. (2011) with a total of 180,930 stations that include the most of France and the North of Africa (North of Morocco and Algeria), but none of them have been made public.

In 2006, the Spanish Government launched the Consolider-Ingenio Program which main goal was to promote scientific innovation in all areas of knowledge. Topo-Iberia (http://www.ictja.csic.es/gt/rc/LSD/PRJ/indexTOPOIBERIA.html) is a Consolider-Ingenio project (http://www.proyectos.cchs.csic.es/csd-tcp/en/content/el-csd-tcp/consolider-program-ingenio-2010) that involves more than 100 PhD researchers from 10 different groups. It corresponds to the willingness and interest of the Spanish scientific community to establish an integrated framework to develop multidisciplinary geoscientific studies in our country. The objective of Topo-Iberia is to understand the interaction between deep, surficial and atmospheric processes, by integrating research on geology, geophysics, geodesy and geotechnology. Three major domains of research have been identified: the southern and northern borders of the Iberian plate (the Betic-Rif system and the Pyrenean-Cantabrian system) and its central core (Meseta and Central-Iberian systems). It is intended to build up a comprehensive, multidisciplinary archive of data and results to tackle the key existing questions by developing novel interpretation strategies. A major aim of this programme is to significantly increase the high-quality information available, by deploying a technological observatory platform, IberArray, of high resolution multisampling and to compile and made available to the scientific community a complete geophysical cartography covering the Iberian Peninsula. With this programme, our community could join the leading edge of international research, marked by similar initiatives, such as TopoEurope/EuroArray in Europe or the ongoing US programme Earthscope.

AIMS AND SCOPE

The aim of this work is the compilation of available gravity data over the Iberian Peninsula following strict quality control procedures to improve the spatial resolution compared to previous compilations. Another goal is to made the improved gravimetric database public accessible through the Internet in order to make it available to the scientific community. IGME is providing the technical support for this task. Moreover, this compilation will help to identify possible areas of interest that might need a more detailed survey.

The present gravity data compilation has been carried out within the frame of the TopoIberia project. For this purpose, several Institutions (the Instituto Geológico y Minero de España, IGME; the Universidad de Granada, UGR; the Universidad de Oviedo, UniOvi; and the Bureau Gravimetrique International, BGI) have contributed with their data.

Until the Inspire directive provides a European standard for the gravity databases, the structure of the Bureau Gravimetric International (BGI) gravity database has been used as a template. In this way, the data is stored in a way that facilitates the exchange of the gravity data assessing its quality. The BGI template has been slightly modified to fit all the available information regarding the input data.

A database that facilitates the interchange between different institutions has a number of benefits for the scientific community and other potential users, as Murray and Tracey (2001) point out:

- Accuracy of the information: having a standard (that should be widely publicised) will help users and future contributors of the gravity data to evaluate more easily the significance of their data and its applications according to its spatial distribution and precision. One of the fundamental aspects is the specifications of key fields of the database. For instance, some parameters that may not be considered as important for some people, such as the base map projection, become critical when divers data sets are assembled into a global database.

- Compatibility: a commonly established standard will facilitate the seamless transfer of data between users (academia, governments, industry and so on).

- Integrity: standard specification of field definition, measurement units, equipment and accuracy, etc., will avoid mistakes and false assumptions and ensure that the data are self contained and recoverable in the future. The standard includes as much information as possible about the survey meta-data in order to ensure that the information about timing, instruments, etc., are transmitted digitally with the point data rather than being filed as hard copy in one organisation's archives with the risk of loosing vital information about the data (accuracy, for instance) that might lead to overinterpretation.

Up to date, only IGME has a public available geophysical database (gravity, magnetics, seismic, well logs, etc.) that can be accessed directly via Internet (http://cuarzo.igme.es/sigeco/default.htm). Actually IGME has 118620 gravity points, 105018 with coverage of 1 point every km^2 or less (structural gravity) and 13602 with coverage between 0.01 and 1 point per km^2 (regional gravity). The new database will have, over the Iberian Peninsula, a total of 160397 point data, 105543 stations with coverage of 1 point every km^2 or less and 54764 with coverage from 0.01 to 1 point per km^2 (those stations include the Balearic Islands).

GRAVITY DATA COMPILATION AND HOMOGENEIZATION

The first step of the data compilation was making a *call for data*. As mentioned in the Introduction, BGI, IGME, UGR and UniOvi contributed providing their respective datasets. Spanish data from BGI and IGME include data collected by IGN, IGME and the Servei Geològic de Catalunya.

The initial data file contained a total of 494677 stations. After a careful selection and analysis of this file that leaded to the deletion of duplicates and *bad points* (see the section GRAVITY DATA MAPPING AND ANALYSIS for an explanation about how the identification of *bad points* was made), the final selection was 459845 points covering the Iberian Peninsula, Balearic Islands, the major part of France and North of Africa (Table I), approximately an area from -15 to 7 degrees in longitude and from 28 to 47 degrees in latitude. It has been checked that all the data is tied up with the IGS71 (International Gravity Standardization Network 1971) reference system.

Organization	**Number of selected points**	**Points / km^2**
BGI	300339	0.67
IGME structural gravity	104768	≤ 1
IGME regional gravity	44880	0.01 a 1
UGR	5018	0.4 a 2.6
UniOvi	4840	Up to 0.2
Total selected points	459845	

Table 1 – Summary of the points given by the different Organizations after revising and eliminating the "bad points". The last column indicates the point density for each dataset.

The procedure for selecting the final data has been as follows:

<u>1- Metadata analysis</u> – The first step was making a summary of the information contained in the different files and the units in which this information was provided: coordinates system (projection and datum), elevation (whether it was orthometric or ellipsoidal), observed gravity (whether it was absolute or relative), topographic correction (if the station had any and the distance to which the correction was performed), reduction density, free air and Bouguer anomalies (and the formulas by which they are calculated, i.e. whether the calculation was made in the GRS67 or the GRS80 geodetic system) and some additional information that might add up in order to evaluate the quality of the data (e.g., instrumentation used in the survey for acquiring the coordinates, elevation and observed gravity, repeat readings, error estimate).

2- Design of the database - The database (Appendix 1) is based on the BGI database format and consists of a main table and a set of auxiliary tables. The main table contains all the required information in order to assess the quality of the data and evaluate its suitability for a given geophysical study trough a series of codes described in the auxiliary tables.

2.1 Main database table

This table (Appendix I) contains the essential information to work with the gravity data weighting up the associated uncertainties and some additional information (e.g. instrumentation used in the survey, etc.). The codes of the table are detailed in different tables in the section *GENERAL CODES* of Appendix I. The parameters of the main database table are the following:

Coordinates which are provided in UTM30N in m and longitude/latitude in decimal degrees referred to the ETRS89 (columns X_ETRS89, Y_ETRS89; LONG_ETRS89, LAT_ETRS89). The accuracy of the position is given in the POSIAC column and the positioning system employed is specified in POSISYS

Elevation- Orthometric elevation in m. ALTITOP describes the type of altitude (topography, bathymetry or other); ALTIAC is the accuracy of the elevation and ALTIDET describes the method used in the acquisition.

Observed gravity in mGal is placed in the VALU_GOBS; OBSTYPE is the type of observation (if the data corresponds to an ordinary station, belongs to a national networks, etc.), GOBS_AC describes the accuracy of the observed gravity and CODE_TYPE is the type of gravity survey (land, satellite, marine, etc.)

Topographic correction has been itemized, whenever possible, into near (VALU_CTP) and total (VALU_CTT) topographic correction, calculated using a density of 2670 kg/m^3. TERCORINF indicates the distance to which the correction has been calculated.

Free Air and Bouguer anomalies have been determined in the geodetic system GRS80 with orthometric heights (FA_Zorto_GRS80, BA_Zorto_267_GRS80). FA_AC and BA_AC are the accuracy of the calculations. The Bouguer density reduction is 2670 kg/m^3.

CODE_TYPE refers to the type of gravimetric survey (structural, regional, etc.). The definitions of the different types of gravimetric surveys are provided in the table with the code description.

GMETER indicates the gravity meter used in the survey (same numbering as in BGI table).

CONFID indicates if the information can be used freely or an authorization for its use is needed.

-9999 is the dummy value used when a given data is not available

3- Homogenization of the data and anomalies calculation – The first step was to transform from each dataset's native coordinates (that came in different systems and projections) into two coordinates system, UTM30N and longitude/latitude, both referred to the ETRS89 datum. One of the difficulties in performing this task was that not all the datasets had the necessary information regarding the coordinates system and projection. This problem was solved by comparing the location and values of the observed gravity and elevation of two stations that seemed to be placed at the same location (±200 m, which is the difference between projecting into ED50 or WGS84/ETRS89) but belonging to a different datasets (one with known coordinates).

The second step was to separate the stations with topographic correction computed to a distance equal or greater than 22 km from the ones without topographic correction or with topographic correction calculated to a distance smaller than 22 km. From the later group 15267 points in France and North Africa were discarded. Because the IGN has available MDT's of 5, 25, 50 and 100 m, the topographic correction up to 22 km was calculated for the points over the Iberian Peninsula without topographic correction (9 from the Oviedo University and 372 from Granada University). Therefore, all the selected points that have been incorporated to the final database have a topographic correction either up to 22 km or up to 167 km.

Fullea et al. (2008) demonstrate that in order to attain an accuracy of 0.1 mGal in the Bouguer anomaly calculation, the minimum distance required for the topographic correction is 20 km even in rough areas. Moreover, some of the surveys were carried out using barometric heights that has accuracy between 1 and 5m which equates in an uncertainty of c. 0.3 to 1.5 mGal in the gravity anomaly. In addition, an error of 100 metres in latitude will result in about 0.05mGal error in the gravity value. For all those reasons the topographic correction up to 167 km for the stations with topographic correction up to 22 km has not been recalculated since this calculation will not improve the accuracy of the data.

Due to the extensive use of GPS technology in gravity surveying, it is recommended the use of the ellipsoidal height for the Bouguer anomaly calculation (eg. Fairhead at el., 2003; Hinze et al., 2005). For this database, where most of the elevations were provided as orthometric heights, the conversion between orthometric and ellipsoidal height was performed using the global geoid EGM08 tailored for the Iberian Peninsula, with elevation resolution of 3.8 cm (EGM08-REDNAP; IGN, 2010) and the EGM08 elsewhere. Everywhere the geoid is made available with a 1' x 1' (approximately 1.85 x 1.85 km) horizontal resolution, which means that interpolation will be required to convert orthometric heights into ellipsoidal heights when the stations are nearer than this resolution. The available DTM's in the Iberian Peninsula are supplied as orthometric heights therefore the Free Air and Bouguer anomaly have been calculated using the GRS80 formulas proposed by Hinze et al. (2005). Two sets of calculations have been made, one with orthometric heights and another one with ellipsoidal heights so the user can easily choose whichever is most convenient. In the present work, for analysis and interpretation of the gravity anomalies, the ones calculated with orthometric heights have been used. Please note that the difference between the reference level for the orthometric heights in Spain (Mean Sea Level in Alicante) and in France (Marseille) is only 2 cm (numbers are taken from http://www.bkg.bund.de). The fact that this difference have not been taken into account in the calculations equates in an additional uncertainty less than 0.008 mGal.

The topographic correction and the Bouguer anomaly have been calculated using a density reduction of 2670 kg/m^3. The choice of this value for solid-earth material above/below the datum is based upon an approximation to the average density of the Earth relative to this datum (e.g. Hinze, 2003).

GRAVITY DATA ANALYSIS AND MAPPING

The objective of this section is, on one hand, explaining the procedure to identify the points in the database that present errors in order to proceed with its elimination and, on the other hand, make a spatial analysis of the point data distribution in order to assess the dimensions of the geological structures that can be investigated with the data, suggesting a grid spacing for studies that encompass the whole Iberian Peninsula.

<u>1- Errors identification from statistical analysis</u> - After the anomalies calculation and prior to data analysis, it is necessary to identify the possible errors and eliminate the *bad points* from the database in order to draw the final map (contours and image). The statistical analysis of the data show a few points that might be outliers. Comparison between those points, the ones around them and the surface geology indicates that they are coherent with the rest of the data.

In addition to the statistical analysis, other criteria can be applied in the search for errors: presence of spikes and/or breaks in the anomaly pattern, anomalies that do not follow the surrounding trends, etc. In general, unless there is a sharp lateral change in density due to a fault or other geological *discontinuity*, it is expected that the gravity data follows certain behaviour:

- Smooth and coherent variation across a given area.
- Major anomalies have to be created by more than one station (i.e., no spikes).
- Trends, patterns and lineaments must have continuity across different gravity surveys.
- The short to medium wavelength anomalies should be consistent with surface geology.

From this analysis, no *outliers* were identified.

<u>2- Error identification from gridding. Search radius and grid spacing</u> – Another way of searching for errors are going from the unevenly distributed points to a grid, which requires choosing a suitable interpolation method. A grid is also useful for working with the data (display, analysis, modelling etc.).

Smith and Wessel (1990) concluded that, for a rather homogeneous distribution of the stations, the best interpolation method for gravity data was minimum curvature, where by adjusting the tension parameter, large oscillations and extraneous inflection points are avoided.

The problem to grid the stations in this database is that its distribution is extremely inhomogeneous: on the Iberian Peninsula, some points can be as far as c. 50 km apart like in Portugal whereas it occurs that in several places points are separated c. 200 m (e.g. the SW of Spain). For that reason, following Sambridge et al. (1995), the gridding procedure chosen consists of first creating a TIN (which is a triangulated mesh of faces that describes a surface, made by interpolating the data) and then gridding the TIN with the Natural Neighbour algorithm.

Once created the TIN the following step is to select the interpolation radius and the grid spacing. The recommended interpolation radius is one that fulfils:

$R=8*(1/\delta)*\pi$ where δ is the point density (points per km^2) (Fernàndez and Marzán, 2010)

The point density varies, in average, between 0.05 and 15 points/km^2, which, according to this formula, gives an interpolation radius between c. 4 and 65 km

The suggested grid spacing has to meet the condition $d/4 \leq A \leq d/2$, where d is the distance between points. According to this formula, taking the maximum separation between points, the grid spacing will be between 12.5 and 25 km, but with this grid spacing there is an important loss of spatial resolution in places where the points are close by. On the other hand, with the 200 m separation a rather unrealistic grid spacing of 50 to 100 m is obtaining, which could create artefacts where the density of points is smaller. The adopted solution of compromise is to calculate the grid spacing from the weighted average distance between TIN nodes, which is 2000 m.

After thorough inspection of the grid, a total of 291 points have been identified as “atypical values” and eliminated from the database: careful examination of the Bouguer anomaly at those points showed that they were inconsistent with that of their surroundings and therefore considering them as *bad points* was justified. Further analysis led to the conclusion that, for some stations, the source of error was the observed gravity whereas in other stations, comparison of the associated elevation with the MDT100 values clearly indicated that the source of error was in the elevation.

Once the database has been cleaned, since the study area targeted in the TopoIberia project includes the Iberian Peninsula and Balearic Islands, South of France and North of Africa, extending from -11 to 5 degrees in longitude and 34 to 45 degrees in latitude (in UTM projection, zone 30 N, datum ETRS89[1] the coordinates are -300000 to 1250000 northing and 3800000 to 5050000 easting), a subset of the database which contains 279420 stations was selected (Figure 1).

[1] From now this projection and datum will be referred as UTM30N

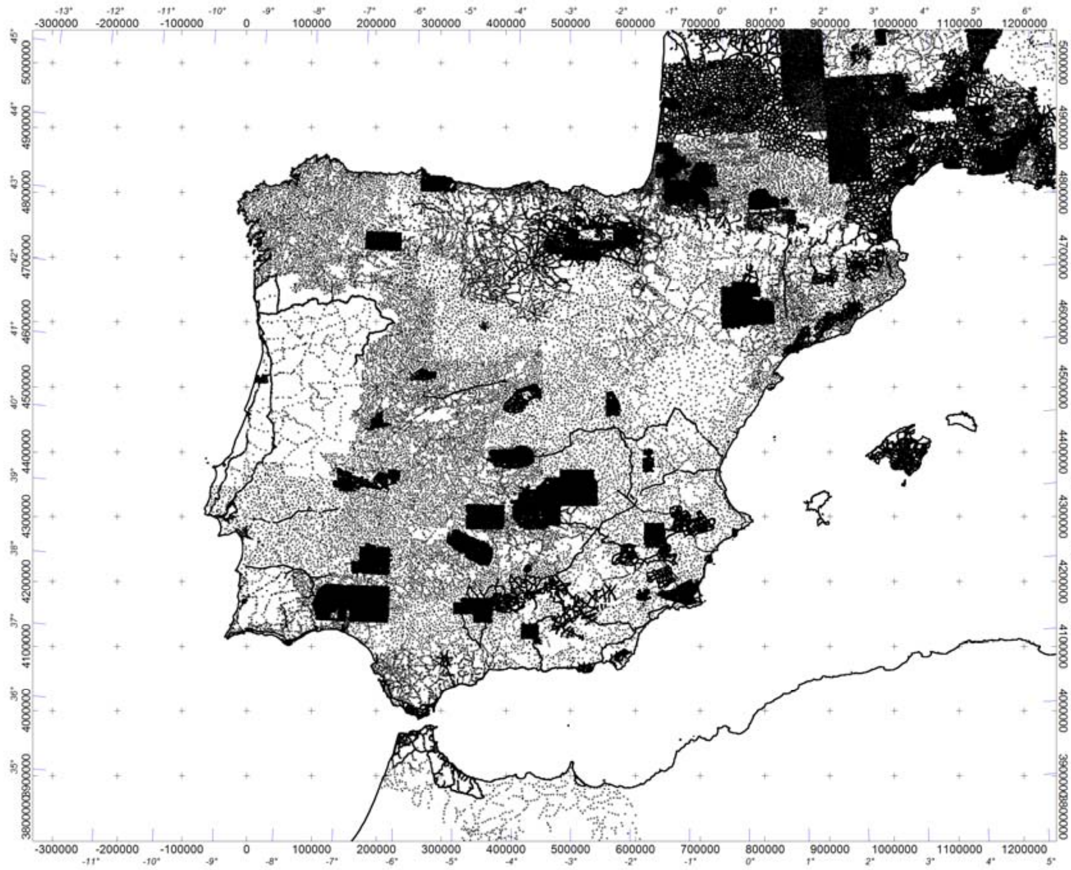

Figure 1 – Points of the database over the Iberian Peninsula (279420 stations) once eliminated the duplicates and the "bad" points corresponding to the selected region.

In order to have a regional image of the gravity distribution and variations over the Iberian Peninsula and its surroundings it has been added, from global databases, some data offshore and on North Africa (but only in places where the BGI data did not have the topographic correction). Offshore it has been taken the satellite derived global marine data (free air anomaly) from Sandwell and Smith (2009) with a spatial resolution of 1 minute. On North Africa, east of -1.8º W, Bouguer gravity anomalies come from a 2.5 minutes grid, derived from the EGM08 and downloaded from the Bureau Gravimètrique International web page. In this way, the stations distribution covers an area large enough to avoid edge effects when carrying out 2D or 3D modelling,

The map with the Bouguer anomaly from the database together with the added data from global databases is displayed as a coded colour point data on Figure 2.

3- Map resolution - The size and depth of the bodies to be modelled determine the optimum observation spacing of any gravity survey. But in this case, where the gravimetric database already exists, what have to be determined are the dimensions of the geological structures that can be targeted.

When planning a gravity survey, the optimum observation spacing is determined for the size and depth of the bodies about to be investigated. Sampling theory indicates that the observation spacing should be approximately half the wavelength of the targeted anomalies. Therefore, it is possible to detect anomalies from bodies at least twice the size of the grid spacing but in order to define its shape, at least three times the grid size is needed (in a profile view, this is equivalent to two points on top of the body and one more point at each edge). Due to the huge inhomogeneity on the data distribution, the resolution varies across the study area (Figure 3): distance between neighbouring points varies from 200 m (pink areas) to 50000 m (orange areas). This map, which only contains the gravity points of the TopoIberia database, is a guide to estimate the resolution that can be expected in the different zones of the study area.

The Sandwell and Smith data has a grid spacing of c. 2000 m. Being this value within the average of the map resolution discussed on subsection 2, the value of 2000 m as the final grid spacing has been kept for the whole dataset (Bouguer onshore and free air offshore). Nonetheless, some places where coverage is below the average (e.g. southern part of the Iberian Chain or the central part of the Pyrenees, with values ranging from 5000 to 10000 m), the interpretation of the gridded data has to be made with caution, and a grid spacing of at least 5000 m would be preferable. Moreover, there are zones with very poor spatial resolution (e.g. the northern half of Portugal or North Africa), where a 10000 m grid would be recommended in case of carrying out a more local study.

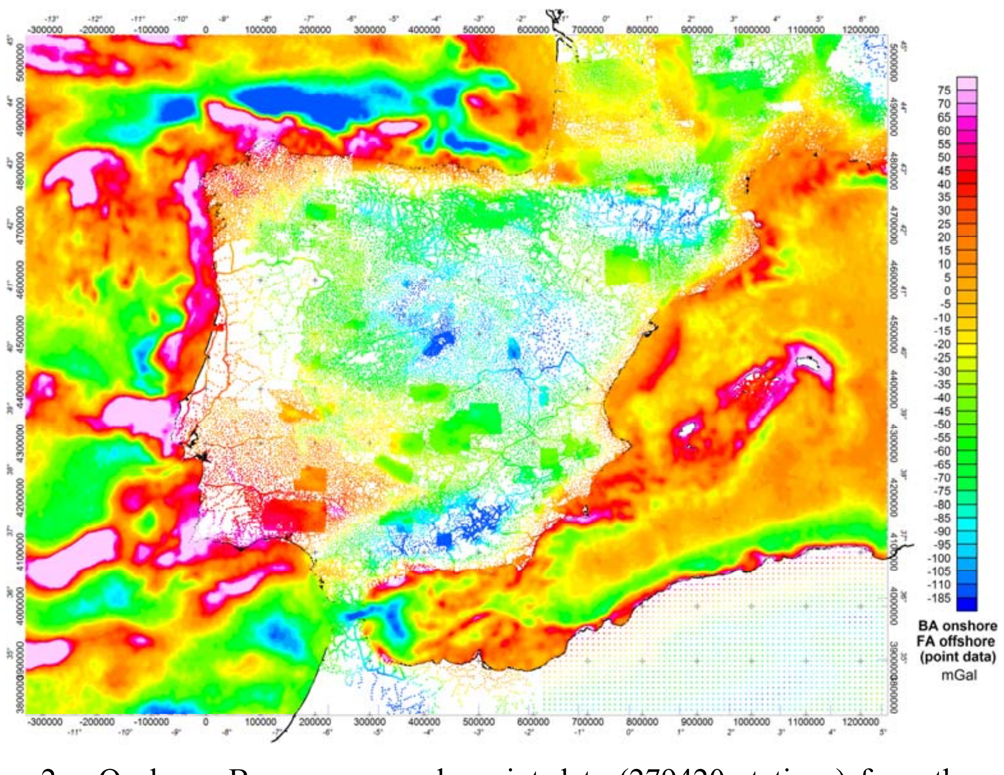

Figure 2 – Onshore: Bouguer anomaly point data (279420 stations) from the present work database over the Iberian Peninsula and surrounding areas (except in N. Africa, east of -1.8º W, where Bouguer anomaly data is derived from the EGM08). Offshore: Free air anomaly point data from Sandwell and Smith (2009). Colour scale has been designed to optimum visualization of the Bouguer anomaly on the Iberia Peninsula, hence the somewhat odd values at the end of the colour scale.

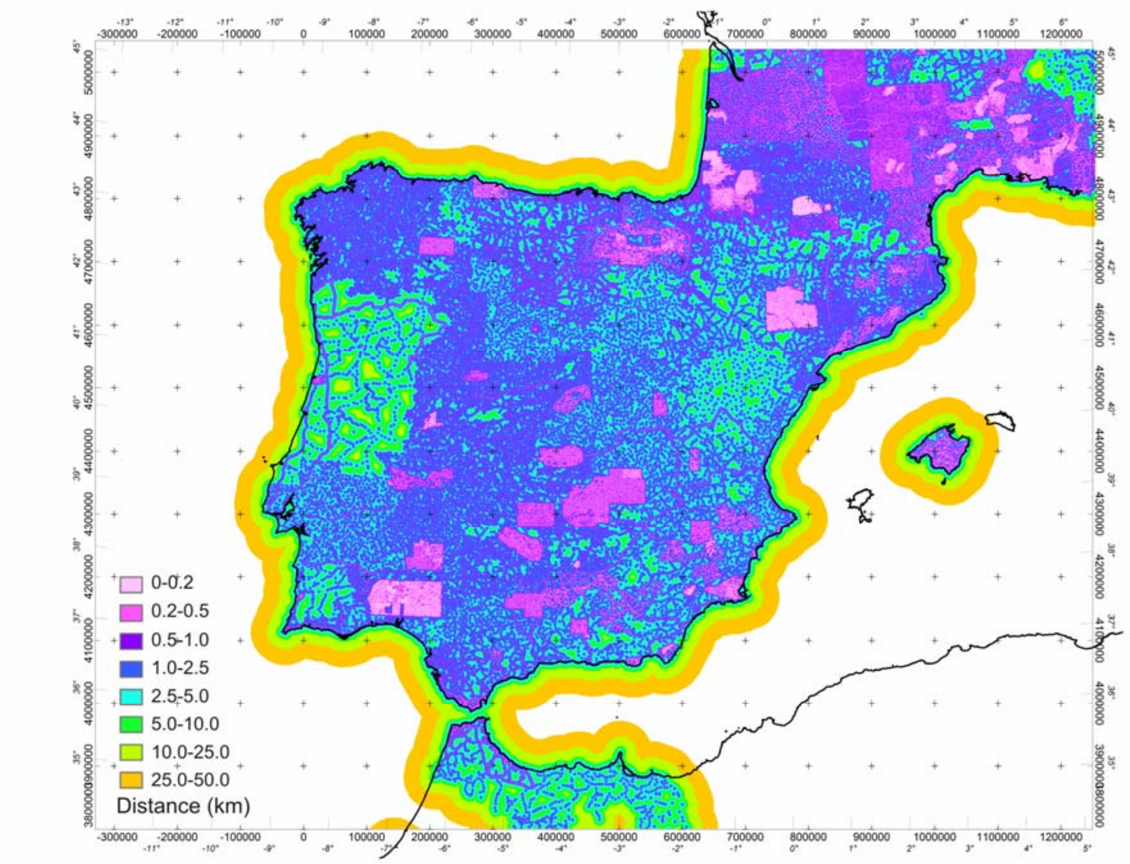

Figure 3 – Distribution of the Euclidean distance between neighbouring points over the Iberian Peninsula.

The discussion about gridding and mapping resolution has been kept brief since the main objective of this report is to present an improved compilation of gravity data over the Iberian Peninsula and surrounding areas. The issue about gridding has been discussed in length in previous works, eg. Rubio and Plata (1998), Smith and Wessel (1990) or Sambridge et al. (1995)

The interpretation of the Bouguer anomalies in terms of the subsurface geology is beyond the scope of this Report, but several related studies have already been carried out and presented in several publications (e.g. Mezcua et al., 1996; Álvarez, 2002, Gómez-Ortiz et al., 2011).

CONCLUSIONS

A new gravimetric database integrating data from four different sources (BGI, IGME, UGR and UniOvi) has been build taking into account the standards proposed by Hinze et al. (2005) regarding the Bouguer anomaly calculation. The most important update is the use of the ETRS89 as geodetic reference system which the associated GRS80 ellipsoid (as established in Spain by law, BOE-A-2007-15822) and making the calculations using the geodetic system GRS80 (with orthometric heights) thus making the database compatible with the actual European standards.

The database contains 459845 data points onland unevenly distributed. Specifically for the Iberian Peninsula and surrounding areas, comprising France and the North of Africa, the number of points is 279420 a significant improvement from previous compilations (the last known compilation to date is from Gomez-Ortiz et al., 2011 and has 172930 points). The average spatial resolution for the Iberian Peninsula is 1 point each 2.25 km^2 which allows gridding with grid spacing of 2000 m.

The database includes all the information available about stations, instruments, observations, calculated quantities and accuracy of the different magnitudes involved in the calculations in order to assess the resolution of the Bouguer anomaly interpretations while investigating crustal and lithospheric structures.

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Appendix I

MAIN TABLE

HEADER	DEFINITION	Code (se next page)
X_ETRS89	X Coordinate ETRS89UTM30N in m	
Y_ETRS89	Y Coordinate ETRS89UTM30N in m	
Z_ORTO	Orthometric elevation in m	
ALTITTYP	Code altitude type	[1]
ALTIAC	Accuracy altitude	[2]
ALTIDET	Code altitude determination	[3]
LONG_ETRS89	Longitude ETRS89 hexadecimal degrees	
LAT_ETRS89	Latitude ETRS89 hexadecimal degrees	
POSIAC	Position accuracy	[4]
POSISYS	Positioning system	[5]
OBSTYPE	Observation type	[6]
VALU_GOBS	Observed gravity, mGal	
GOBS_AC	Observed gravity accuracy	[7]
VALU_CTP	Near topographic correction, mGal, 2.67 g/cm3	
VALU_CTT	Total topographic correction, mGal, 2.67 g/cm3	
TERCORINF	Distance topographic correction calculation	[8]
FA_Zorto_GRS80	Free air anomaly, orthometric height GRS80, mGal	
FA_AC	Accuracy free air anomaly	[7]
BA_Zorto_267_GRS80	Boug. anomaly, orthometric height 2.67 g/cm3, GRS80, mGal	
BA_AC	Accuracy Bouguer anomaly	[7]
CODE_TYPE	Type of gravity survey	[9]
GMETER	Gravity meter type (same as BGI)	[10]
CONFID	Confidentiality of the information	0=No; 1=Yes (*)

(*) Authorisation required for using the data

CODES USED IN THE MAIN TABLE

[1] ELEVATION TYPE

ALTITTOP	INF_ALTITTOP
1	Topography
2	Bathymetry
3	Other

[2] ELEVATION ACCURACY

ALTIAC	INF_ALTIAC
0	No information
1	less than 0.02 m
2	0.02 to 0.5 m
3	0.5 to 1 m
4	1 to 2 m
5	2 to 5 m
6	greater than 5 m

Elevation accuracy comes from the way elevation was determined i. e., is related to the accuracy of the measurements instrumentation (see table [3]).

[3] DETERMINATION OF THE ELEVATION

ALTIDET	INF_ALTIDET
0	No information
1	Geometrical levelling (bench mark)
2	Barometrical levelling
3	Trigonometrical levelling
4	topographic map
5	Satellite
6	GPS

[4] POSITION ACCURACY

POSIAC	INF_POSIAC
0	No information
1	Les than 5 m
2	5 to 20 m
3	20 to 100 m
4	100 to 200 m
5	200 to 500 m
6	more than 500 m

[5] POSITIONING SYSTEM

POSISYS	INF_POSISYS
0	No information
1	GPS
2	Topographic map
3	Other

[6] OBSERVATION TYPE

OBSTYPE	INF_OBSTYPE
0	No information
1	3rd or 4th order network
2	2nd order national network
3	1st order national network
4	observation being part of a nation calibration line
5	Ordinary observation
6	Base station

[7] GRAVITY ACCURACY (Gobs, free air, Bouguer)

GOBS_AC	FA_AC	BA_AC	INF_G_AC
0	0	0	No information
1	1	1	microGal
2	2	2	0.01 to 0.05 mGal
3	3	3	0.05 to 0.1 mGal
4	4	4	0.1 to 0.5 mGal
5	5	5	0.5 to 1 mGal
6	6	6	1 to 3 mGal
7	7	7	3 to 5 mGal
8	8	8	greater than 5 mGal

[8] INFORMATION ABOUT TERRAIN CORRECTION

TERCORINF	INF_TERCOR
0	No topographic correction
1	TC computed for a radius of 5 km (zone H)
4	TC computed for a radius of 167 km (zone 02)
14	Unknown radius
15	TC computed to zone M (22 km)

Please note that those codes are the same as the ones from BGI data format, hence the apparently odd numbering. More codes can be added in the future if needed.

[9] TYPE OF GRAVITY SURVEY

CODE_TYPE	DESC_DATA
0	No information
1	Structural
2	Regional
3	Microgravity / detailed / time lapse microgravity
4	Undetermined
5	Satellite gravity
6	Marine tracks

Definitions –

Structural gravity survey – Land measures with a point distribution between 1 to 5 stations per square kilometre. Correspond approximately to a 1:50000 scale map.

Regional gravity survey – Land measures with a point distribution of less than 1 station per square kilometre. Typically about 1 point every 10 square kilometres. Correspond approximately to a 1:200000 scale map.

Microgravity survey – Measures where the point separation is of the order of tens of meters (preferably 200 m or less) and the accuracy is of the order of microGal. It is recommended (but not essential) to acquire the data at regular intervals (along a profile or a grid).

Detailed survey – Measures where the point separation is less than 500 m but the accuracy of the measures could be of the order of cmGal.

Time lapse microgravity survey – Measures with accuracy of the order of microGal acquired in stations that are accurately re-occupied over a period of time.

[10] GRAVITY METER USED FOR THE MEASUREMENTS

GMETER	INF_GMETER
0	No information
42	Askania GS-4-9-11-12, Graf metal spring gravimeter for ground measurement
44	North American metal spring gravimeter for ground measurement
47	Lacoste & Romberg
53	Worden ordinary
54	Worden (additional thermostat)
591	Scintrex CG2
592	Scintrex CG3
593	Scintrex CG5

Please note that those codes are the same as the ones from BGI data format, hence the apparently odd numbering. More codes can be added in the future if needed.