BOLLETTINO DI GEOFISICA TEORICA ED APPLICATA VOL. 40, N. 3-4, pp. 205-210; SEP.-DEC. 1999

Gravimetry data validation in Algeria

S.A. BENAHMED DAHO and S. KAHLOUCHE

National Centre of Spatial Techniques, Geodetic Laboratory, Algeria

(Received October 4, 1998; accepted August 5, 1999)

Abstract. A Method for the validation of gravity measurements using the Least Squares Collocation (LSC) method and Gravsoft software of Copenhagen University is applied on a small zone in Algeria. The gravity data, provided by the B.G.I., consisting of 12472 gravity measurements covering the region, were analysed and validated. The validation has been applied systematically to predict free-air gravity anomalies reduced from the effect of the spherical harmonic coefficient set OSU91A. The detected gross errors represent 4.7% of the land data. This work shows the non-homogeneity of the data used and their insufficient accuracy.

1. Introduction

Validation is an extremely strict procedure that guarantees quality and integrity of the gravity data bank. It is applied systematically to all sets of data before being integrated into the data bank. The principle consists of comparing the observed value and the predicted one estimated by a powerful technique.

The object of this work is to present a method for validation of gravity measurements on small zones in Algeria.

In this context, the validation has been systematically applied to predict free-air gravity anomalies reduced from the effect of the spherical harmonic coefficient set OSU91A using the least squares collocation. The results obtained (error ratio) allow us to make a statement on the quality of the data used.

2. Gravity anomalies

Gravity anomalies used in this work, and composed of 12 472 land data covering the

---

Corresponding author: S.A. Benahmed Daho; C.N.TR.S. BP 13, Arzew 31200, Algeria; phone: +213 6 47 2580; fax: +213 6 47 3452; e-mail: d_benahmed@hotmail.com

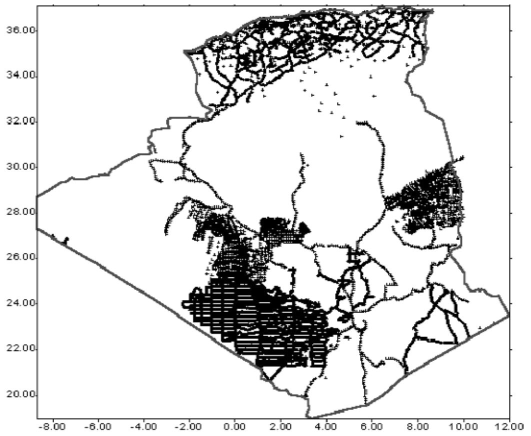

Fig. 1 - Geographical distribution of gravity measurements.

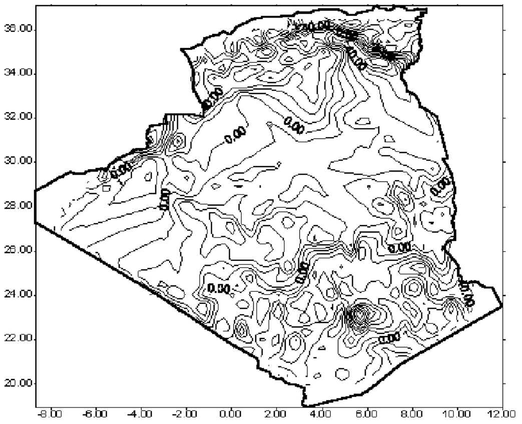

Fig. 2 - Free anomaly isolines contoured at 10 mgals intervals.

territory of Algeria, were supplied by the B.G.I. (Bureau Gravimétrique International). These measurements with an initial precision of 5 mGal were expressed in the Geodetic Reference System GRS67. All gravity measurements were transformed from the GRS67 to the GRS80 system.

Moreover, we applied an atmospheric correction recommended by the International Association of Geodesy (IAG, 1971) in order to eliminate the influence of the atmospheric masses. Figure 1 shows the geographical distribution of the gravity data available and Fig. 2 shows a map of the free-air gravity anomalies contoured at a 10 mGal interval.

This set of data was partitioned into 42 rectangular zones that have been processed separately for numerical reasons. These zones are disjointed and were only used for classification and validation purposes. Figure 3 shows the zone number and the corresponding gravity measurement number in Algeria.

The classification was carried out in two steps ; in the first, a subdivision was made taking as zones every 2° × 2° zone in a regular and continuous way. As a result, this classification shows both the empty zones and those containing few data. In the second step, only the regular zones with a sufficient number of data, and those resulting from the union of adjacent zones with few data, were considered.

3. Geopotential model

The problem of choosing a geopotential model which best fits the gravity field in Algeria has not been solved definitely. In the present work, the model OSU91A (Rapp et al., 1991), complete to a degree and an order 360, was adopted as a reference in order to eliminate the long wavelengths of the gravity field. Gravity anomalies can be computed in a spherical approximation from a geopotential coefficient set by:

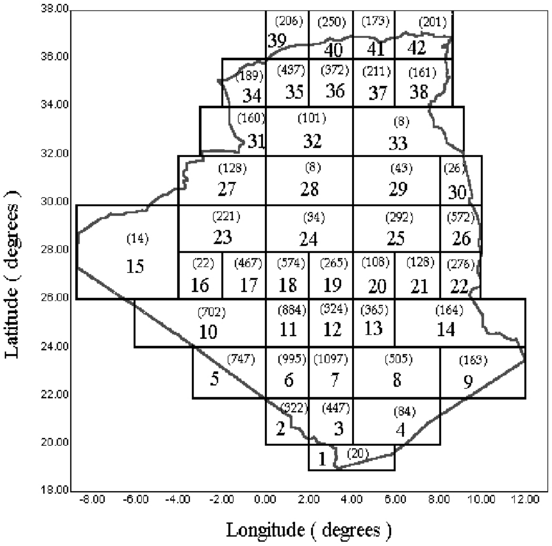

Fig. 3 - Zone numbers and corresponding gravity measurement numbers (in brackets).

$$\Delta g = \frac{GM^{N}}{r^2}\sum_{n=2}^{\max}(n-1)\sum_{m=0}^{n}\left[\overline{C}_{nm}\cdot\cos\ m\lambda + \overline{S}_{nm}\cdot\sin\ m\lambda\right]\ \overline{P}_{nm}(\cos\ \theta) \tag{1}$$

where θ, λ are the geocentric colatitude and longitude of the point where Δg will be determined; C_{nm}, S_{nm} are the fully normalised spherical geopotential coefficients of the anomalous potential; P_{nm} are the fully normalised associated Legendre functions; N_{nm} is the maximum degree of the geopotential model. The statistical of original (observed) anomalies and the corresponding anomalies reduced to the geopotential model OSU91A are given in Table 1. Figure 4 shows a map of the free-air anomalies minus the model gravity anomalies contoured at 10 mGal interval.

4. Estimation of covariance functions

The empirical covariance function of the reduced data was computed for every zone with the EMPCOV program (Tscherning, 1994) using the following formula:

$$C_{ss}(\psi) = \frac{1}{M}\sum \delta\Delta g_i \cdot \delta\Delta gj \tag{2}$$

Where M is the number of combinations, ψ is the spherical distance between Q_i and Q_j and $\delta\Delta g$ is the free-air gravity anomalies reduced to the geopotential model OSU91A.

The summation was made for all the combinations of the data points Q_i and Q_j whose

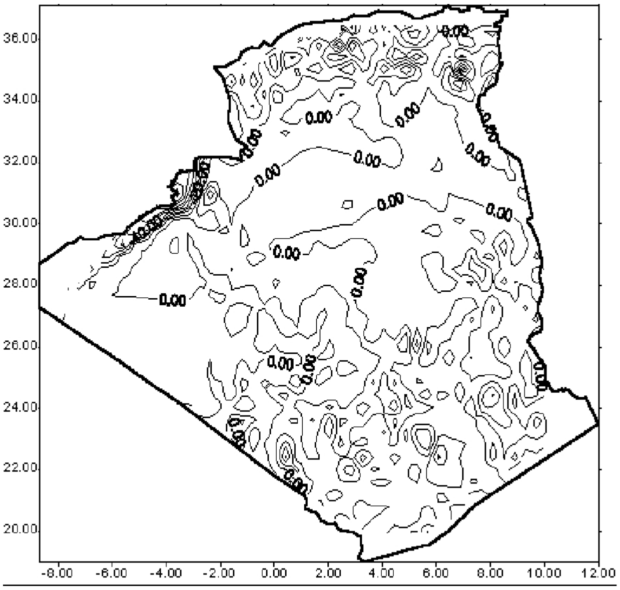

Fig. 4 - Free-air minus model gravity anomalies contoured at 10 mgal interval.

distance was comprised between (ψ–$\Delta\psi$/2) and (ψ+$\Delta\psi$/2), and here $\Delta\psi$= 7.5".

For the calculation of the LSC, an analytic expression of the covariance function was more convenient. We adopted a classical analytic covariance function for the disturbing potential proposed by Tscherning & Rapp (1974), which is expressed by a sum of series of Legendre polynomials (Moritz, 1980) as:

$$K(\psi)=\alpha\left[\frac{GM}{R_E}\right]^2\cdot\sum_{1=2}^{N}\varepsilon_1\left[\frac{R_E^2}{rr'}\right]^{l+1}P_l(Cos\psi)+\sum_{i=N+1}^{+\infty}\frac{A}{(i-1)(i-2)(i+4)}\left[\frac{R_B^2}{rr'}\right]^{i+1}P_i(Cos\psi) \qquad (3)$$

where

ε_1: error degree variances of the reference field,

N: maximum degree of the reference field coefficients (here 360),

α: scale factor of errors associated with the reference field,

R_B: radius of a Bjerhammar sphere,

r and r': radial distances of the points,

R_E: mean earth radius,

A: scale factor of the degree variances.

The actual use of this model as a local covariance function requires the estimation of three parameters: the radius of the Bjerhammar sphere (R_B) and two scale factors α and A.

The adjustment results of the empirical covariance function of the Tscherning & Rapp model

Table 1 - Statistics of BGI gravity data in Algeria.

	Mean	St. Dev	Minimum	Maximum	Range
Latitude (degrees)	26.99	4.72	19.56	37.07	17.51
Longitude (degrees)	2.67	3.13	-8.43	11.32	19.75
Height (m)	499.18	268.82	1.00	2538.00	2537.00
Free -Air (mGal)	5.25	27.43	-82.59	165.37	247.96
OSU91A (mGal)	4.95	24.67	-66.30	99.00	165.30
Free-Air - OSU91A	0.30	13.16	-97.04	125.56	222.60

were obtained by the COVFIT8 program (Knudsen, 1987).

5. Gravity data validation

The validation is a necessary procedure which shows the quality of the data used by comparing the observed and estimated values obtained by using the least squares collocation method.

The reduced data of each zone were divided into two sets A and B which have no common observations, but have the same distribution. From these anomalies, two empirical covariance functions were computed separately for all zones. These empirical values were used in order to estimate the parameter values of a local covariance function model (Tscherning, 1974).

The prediction of gravity anomalies were carried out on all of set *B* using data of set *A*, and compared with the observations of set B. However, if the difference between Δg_{obs} and Δg_{pred} was greater than 20 mgals, the observation was rejected. The same procedure was applied to set *A* with the data of set *B*.

By removing the suspected points in sets *A* and *B*, the procedure is repeated with prediction on all the points of sets *A* and *B* alternatively, and if the same point appears suspect, then we concluded that it has definitively a large error. The error ratio we have detected using this method was about 4.7 %.

6. Conclusion

The method used in this work is not recent in its principle, but it is of major interest for the validation of gravity measurements. These are generally the type of data used in the modelling of local gravity fields.

The error ratio detected using this technique remains high with regard to the number of measures used. The results obtained have shown serious gaps in the gravimetric coverage of the country that are needed to satisfy the requirements of geodesy as well as those of geophysics and geology.

In perspective, for a precise determination of the local gravity field from the validated gravity measurements, it is necessary to have a dense and uniform gravimetric coverage on all the territory.

Acknowledgements. The authors thank Prof. C. C. Tscherning and R. Forsberg for providing the GRAVSOFT software, and Prof. G. Balmino for BGI gravity data on Algeria.

References

B.G.I.; 1993: Information bulletin of the ‘Bureau Gravimétrique International’, N° 72.

Benahmed Daho S. and Kahlouche S.; 1997: *The gravimetric geoid in Algeria: First Results*. Scientific Assembly of the IAG, Rio de Janeiro, Brazil, 3- 9 September 1997.

IAG; 1971: *Geodetic Reference System 1967*. Publ. Spéc. N° 3 Bull. Geod., Paris.

Knudsen P.; 1987: *Estimation and Modelling of the Local Empirical Covariance Function using gravity and satellite altimeter data.* Bulletin Géodésique, **61**, 145-160.

Moritz H.; 1976: *Covariance Function in Least Squares Collocation,* Report N° 240, Ohio State University.

Moritz H.; 1980: *Advanced Physical Geodesy*, H. Wichmann-Abazcus Press, Karlsruhe-Tundridge Wells.

Rapp R. H. and Sansó F.; 1995: *Determination of the geoid: present and future.* International Association of Geodesy symposia, N° 106.

Tscherning C. C., Rapp R. H. and Goad C.; 1983: *A comparison of methods for computing gravimetric quantities from High Degree Spherical Harmonic Expansions*. Manuscripta geodaetica, **8**, 249-272.

Tscherning C. C.; 1974: *A FORTRAN IV program for the determination of the anomalous potential using stepwise least squares collocation.* Reports of the Department of Geodetic Science, N° 212, Ohio State University.

Tscherning C. C.; 1974: *Closed Covariance Expressions for Gravity Anomalies, Geoid Undulations, and Deflections of the Vertical Implied by Anomaly Degree-Variance Models*. Dept. of Geodetic Science, report 208, the Ohio State University.

Tscherning C. C.; 1994: *Geoid determination by Least Squares Collocation using GRAVSOFT.* Lecture notes for the international school for the determination and use of the geoid, Milan, October.