Topex Altimetric Mean Sea Level and Gravimetric Geoid in the North of Algeria

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Abstract. The mean sea level is processed from Topex altimetric measurements collected on the Algerian coasts (on the South West of the Mediterranean Sea) over a three months period (April 20 to July 28, 2000).

The model used, based on the Barrick-85 model, determine the instantaneous sea surface heights for 80 cycles distributed on 8 orbital arcs.

The pre-processing of the raw data permit the selection about 75 % of the measurements. The processing of the fitted data, by polynomial adjustment, is done after the correction of the main disturbed effects (instrumental, atmospheric,...) and the reduction of the radial component of the orbital error. The analysis of the mean arcs in the crossing points by the least squares adjustment allows a centimetric accuracy of the mean sea level.

The surface obtained was extrapolated to the North of Algeria (surrounding the coasts) and compared to a gravimetric geoid calculated with a set of BGI free air gravity anomalies and GETECH data using the FFT techniques implemented in the Geofour program (Tscherning, 1994).

The metric difference obtained is due to the insufficient altimetric and gravimetric data distributions, and to the extrapolation method used. The availability of an exhaustive gravity measurement, particularly the gravity cruise data (sea data), and a long period altimetric measurement, will allow a strong comparison between the surfaces.

Keywords. Altimetry, Topex, Geoid determination, FFT, Mean sea level.

1 Introduction

It is at the beginning of the 70s that satellites began to collect data regularly on the physics, the chemistry and the dynamics of the Earth, oceans, atmosphere and biosphere. It was also the time of first altimetric measurements to determine the oceanic surface topography.

The United States were the first to have made in orbit an altimeter aboard satellites, on Skylab and Geos-c, then on Seasat in 1978 and Geosat in 1985. Since the 90s, new altimetric missions are launched, ERS-1 (1991-1996), Topex (since 1992), ERS-2 (since 1995), JASON (12-7-2001). The role of the ocean in the evolution of the past and future climates is henceforth asserted and demonstrated.

This work is based on the processing and analysis of the Topex altimetric data for the determination of various parameters allowing to calculate the height of the sea above a reference ellipsoid and consequently the calculation of an altimetric mean sea level on the occidental Mediterranean Sea.

The obtained surface (mean sea level) is then extrapolated on the North of Algeria to determine a geoid; the latter is compared with a local gravimetric geoid obtained by FFT technique on the North of Algeria. The gravimetric data used for the first time are provided by GETECH. Several previous works and studies were done on Algeria these last years (Benahmed, 1998), and were based only on the BGI data.

Topex allows altimetric studies due to a radar altimeter and a very successful positioning system Doris loaded in complement to the GPS receiver and Laser reflector. It is so possible to measure with a centimetric accuracy (Bonnefond, 1996) the least variations of the sea level height. And so since March 1992, the Topex satellite observes continuously the movement of the oceans, it is indeed the first time that a systematic and continuous global surveillance of the oceanic circulation is possible. Once the satellite is operational in orbit, and all the on-board equipment function in a normal way, the phase checking the instruments begins, to guarantee quality and validity of scientific data (Aviso, 1996). The objective is to have geophysics data, freed of any instrumental errors to estimate the performance of the developed observation system:

- 2 cm on the altimetric measurements.
- 2 m/s on the wind speed.
- 50 cm on the waves height.

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The satellite altimetry is based on two principles: one physico-optics and concerns the processing, using the Barrick model, of the retrodiffused signal by the sea surface, the modelling of the echo, the wind speed as well as the altimetric observation. The second geometrical and consists of deducting the height of the sea surface with regard to an ellipsoid of reference, from the knowledge of the orbit parameters, the position of the satellite and the altimetric measurements.

2 Topex Orbitography

The determination of the satellite height is the most delicate point for a global mission; a centimetric accuracy on the satellite position with regard to a terrestrial reference system is necessary. This is possible due to the three tracking systems embarked on Topex, which allow to give several informations about the orbit (laser reflectors, GPS receiver, Doris receiver). (Bonnefond, 1994). For altimetric missions it is the radial component of the satellite orbit which requires to be determined with the highest accuracy: indeed, it is the precise knowledge of the satellite height (close to the radial range) which allows completely to use altimetric measurements and to access so to the height of the sea on a reference surface (ellipsoid). This effort of accuracy in trajectography was linked, at first, to the calibration of the Topex satellite altimeters: an equivalent accuracy of altimeters (2-3 cm) is needed (Bonnefond, 1994).

The measure of station - satellite range by Laser telemetry reached actually a high precision (2 cm) and is calibrated (externally or internally) at a superior level (probably lower than 1 cm) (Degnan, 1993). The method of short arcs can so assure the quality of a radial positioning at a centimetric level in absolute.

This method was applied to the calibration of radar altimeters Topex (ALT, NASA) and Poseidon (SSALT, CNES) of the Topex satellite during the pass over the two calibration sites (Harvest and Lampedusa) (Christensen and Ménard, 1994).

The automatic consideration of the pass geometry toward the laser stations, different for the two sites, allowed to obtain equivalent orbits quality: the analysis of the dispersion of altimetric bias (3 cm) and various orbit comparisons during this period (2 cm), show that the main cause of error in the calibration does not result certainly from the orbit determination.

3 The Processing of Altimetric Data

3.1 Altimetric Data Used

The data used are diffused on CD-ROM by the CLS / AVISO company; they correspond to the three months period (20/04/2000 - 28/07/2000).

The data file contains eight passes (009, 070, 146, 085, 172, 187, 248, 161) of the satellite Topex, four ascending (187, 009, 085, 161) and four descending (172, 070, 248, 146). In each of these passes there are ten cycles; distance between two parallel successive passes is about 315 Km. These passes cover the west basin of the Mediterranean Sea, bounded by:

- Meridians 1 ° west and 10 ° East.
- Parallels 35 ° south and 44 ° North.

3.2 Data Filtering

To eliminate erroneous measurements (impact point not located in the sea or collected under unfavourable weather conditions), we have to filter the data; this is based on a series of tests on the indicative parameters of the quality of the measurements. The electromagnetic bias is estimated (Aviso, 1996) at 7 % of the significant waves height, the induced error is estimated to ± 3 % of the significant waves height, observations collected in the presence of the important waves are eliminated (Kahlouche & al, 1998).

As presented on Fig. 1 above, an average of 70% of the initial measurements is included in the processing.

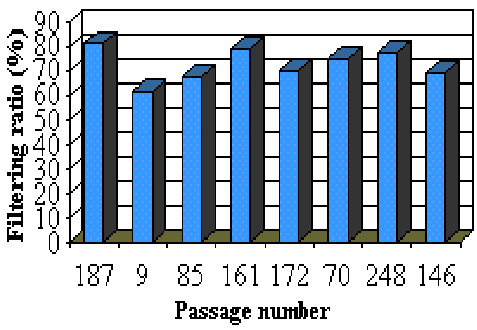

Fig. 1 Rate of measurements included in the data processing

3.3 Corrections

All corrections to raw altimetric measurements are directly extracted from the data file (they are processed before using models and suited algorithms). Nevertheless, there are a number of corrections, which are not available like the oceanic tides (these terms take values by default).

3.3.1 Tropospheric Effects

The disturbance of the signal in the low atmospheric layers (from 0 to 50 Km) is due to the presence of dry air and steam. The correction of the tropospheric effect is given by four parameters deducted from the measurements made with the NASA microwave radiometer (effects of the dry air of the troposphere respectively for the up and down paths, wet air effects) (Stewart, 1985).

The results obtained on 10 cycles show that the correction due to the dry air is rather important. It has an average of 1.33 m with a weak standard deviation (mean=1.1 mm) and correction due to the wet air is very weak, it has an average of 10cm, on the other hand corresponding standard deviation is not negligible (mean=7.6 mm).

3.3.2 Ionospheric Effects

The ionospheric correction applied is on one hand to the average between values given by the bifrequency model of the NASA altimeter (Topex) and on the other hand, by the Doppler measurements made with Doris beacons (Poseidon) (Rummel, 1993). The values are 0.94 cm for the average supplied with the NASA altimeter, and 1.3 cm for Doris.

3.3.3 Instrumental Corrections

The whole of the instrumental corrections are expressed by a single corrective term. Some effects vary with the signal frequency and the orientation of the receiving antenna as well as the satellite orientation (centre of gravity - centre of phase) and it is expressed by an error on the observed range. The obtained results show that the corrections average is not very weak and is about 0.98 m.

3.3.4 Electromagnetic Bias

Electromagnetic bias depends on the state of the sea (wave heights), which is deducted from the intensity of the reflected signal. Its influence is not important for a calm sea but it is considerable for an agitated sea, because as it is not well modelled. It even constitutes a filtering criterion. In our case, the correction to be brought has an average of 11mm.

3.3.5 Tides Effects

The altimetric measurement is also corrected of oceanic tides, solid tides and load effects; these corrections are directly obtained from the Topex data file. The oceanic tides are calculated with two models, the CSR3.0 (empirical model - Texas University), which is an empirical model and the FES95.2 model (semi-empiric assimilation model - Grenoble University - France).

4 Determination of the Average Profile

The average altimetric profile corresponds to a set of average heights of the sea, along the satellite tracks, representative of average sea level for the period of time on which the measurements were collected. This averaging process is used to get free from variable phenomena whose period is less than the considered one. These phenomena can result from variations of the sea surface (seasonal variability, semi-annual, inter-annual) or of the dispersion of altimetric measurements, but also from orbit errors (Kariche, 1997).

4.1 Averaging Process

According to Barrick's model (Stewart, 1985), the processing consists of averaging three parameters (latitude, longitude and height of the sea surface) by gliding of a window of 0.047° (in latitude, that corresponds to the average spacing between two successive satellite measurements). The average is processed if at least 60 % of used cycles are represented in this window. The accuracy of the obtained average points depends on the dispersion of the instantaneous profiles and on the number of averaged points. The results presented in the following Table 1, shows the centimetric accuracy of the cycles of the same Topex pass.

The obtained standard deviations indicate the existence of a variability, so the existence of a dispersal between the cycles of the same pass, and the quality of altimetric data. As shown in the Table 1, the pass number 187 distinguishes itself from the other passes by its coherence and its highest mass of measurements with regard to the others.

Table 1. Standard deviations of instantaneous heights for every pass

Pass number	Cycles number	Number of used points	Average variation (cm)	Standard deviation (cm)
161	10	745	0.33	3.32
172	10	525	1.54	4.47
187	10	874	0.01	3.05
248	10	581	1.95	3.51
070	10	628	0.92	3.73
146	10	497	1.05	4.12
085	10	536	0.97	3.54
009	10	587	1.36	3.84

4.2 Polynomial Adjustment

To fill the absence of measurement along the average profiles, and to densify the zone, the heights of the sea surface are approximately processed by a second-degree polynomial (function of the longitude and the latitude). The polynomial coefficients are calculated with the least squares method. The precision of the adjustment depends on the number of used points and the degree of the polynomial, second order is considered sufficient for our zone of study (Rummel, 1993). The precision of the adjustment is given on the following Table 2:

Table 2. Standard deviations of the polynomial adjustment (for every pass)

n° of passes	Number of average points used	Standard deviation (cm)
161	138	1.98
172	108	2.85
187	152	1.75
248	120	2.14
070	125	2.09
146	91	2.17
085	106	2.68
009	117	2.00

Pass 187 presents a rather small standard deviation (1.75 cm), with a number of used points (152) providing a wide redundancy.

5 Orbit Correction

Using the least square method, the reduction of the radial component of the orbit error, is made (Engelis & al, 1987) by processing in the crossing points (intersection between ascending and descending arcs).

The orbit determination is made from a dynamic model of the movement of the satellite, which takes into account the more possible complete field of force. It is including the more precise field of Earth potential, the effects of the Moon and the Sun, the tides effects, the forces entailing secular drift of the satellite as the drag effects and radiation pressure (Zarouati, 1987). The orbit error is difficult to estimate. It can be estimated either by the comparison of various altimetric measurements in the same point or by processing the orbit from two different parameters. The reduction of the orbit error is achieved generally by two methods (Bonnefond & al, 1994):

- Processing of repetitive passes
- Processing in the crossing points (it is the method mostly used considering its rigorous aspect and the results provided).

5.1 Determination of the Crossing Points

The crossing points are defined by the intersection of ascending and descending arcs.

They are definite, in a window of (10m × 30m) (Kariche, 1997), by a sequential search, their co-ordinates are calculated by the intersection of two diagonals (ascending and descending pass), and the two values of the sea surface height are processed by linear interpolation, with a determination of 10 crossing points (see Fig. 2) in the occidental Mediterranean sea.

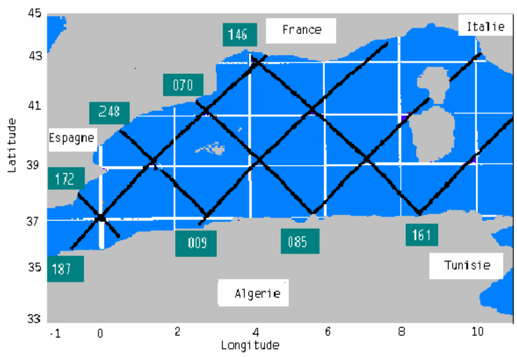

Fig. 2 Crossing of Topex's tracks in the occidental Mediterranean Sea

The height differences in the crossing points show the existence of orbit errors. The obtained deviations are representative of the error differences (including variability), which allow us the comparison of errors along the ascending and descending passes.

Table 3. Differences of heights in the crossing points

Passes crossing	longitude(°)	latitude(°)	Height differences Dh (cm)
187 and 172	0.004623	37.10601	-42.8
187 and 248	1.422921	39.21632	94.9
187 and 070	2.840221	41.17225	09.4
187 and 146	4.257571	42.98526	45.9
009 and 248	2.840395	37.10358	107.5
009 and 070	4.257317	39.21056	86.2
009 and 146	5.646207	41.10448	65.0
085 and 070	5.673849	37.10401	03.9
085 and 146	7.063431	39.13961	-100.7
161 and 146	8.509435	37.10295	-18.4

5.2 Orbit Error by Processing in the Crossing Points

The determination of the orbit errors by processing in the crossing points is made from the equation of observation (two parameter model) which is represented in the form (Rummel, 1993):

$$h_i - h_j = d_{ij} = a_i - a_j + b_i s_i - b_j s_j \tag{1}$$

Where:
a_i, aj: respectively bias for the pass i and pass j
bi, bj: drift parameters with regard to the same origin respectively for passes i and j.
dij: height differences (h) in the crossing points.
si, sj: distances (in km) along every track between the crossing points and the origin, which is common for every pass.

The approached values (a_0 and b_0) of the parameters (a and b) can be processed (for every pass) by comparison of the altimetric surface height with the geoid deducted from the global potential models as OSU91.

$$h - N = a_0 + b_0 s \tag{2}$$

Where:
N : indicates the geoid height deducted from the geopotential model.

By introducing the approached values in equation (1), we obtain: (3)

$$d_{ij} - (a_{0i} + b_{0i} s_i - a_{0j} - b_{0j} s_j) = \delta a_i - \delta a_j + \delta b_i s_i - \delta b_j s_j + v_{ij}$$

With:

$$\delta a = a - a_0 \quad , \quad \delta b = b - b_0$$

In matrix form, equation (3) becomes:

$$c_{ij} = \begin{bmatrix} 1 & -1 & s_i & -s_j \end{bmatrix} \begin{bmatrix} \delta a_i \\ \delta a_j \\ \delta b_i \\ \delta b_j \end{bmatrix} + v_{ij} \tag{4}$$

Where:

$$c_{ij} = d_{ij} - (a_{0i} + b_{0i} s_i - a_{0j} - b_{0j} s_j) \tag{5}$$

Note that the number of equations is equal to the number of crossing points (m), the number of unknowns is equal to twice the number of passes (if the passes have equivalent lengths).
The system of equations transforms to:

$$B = A X + V \tag{6}$$

With :
X : parameters vector,
B : data vector,
A : resolution matrix
V : residual vector.
Where the solution:

$$X = (A^T P A)^{-1} (A^T P B) \tag{7}$$

With P is the weight matrix
The approached values of the parameters a_{0i}, b_{0i} can be also calculated (for every pass i) by least square method by solving the following normal system (Rummel, 1993):

$$\begin{bmatrix} m & \sum_{k=1}^{m} s_k \\ \sum_{k=1}^{m} s_k & \sum_{k=1}^{m} s_k^2 \end{bmatrix} \begin{bmatrix} a_{0i} \\ b_{0i} \end{bmatrix} = \begin{bmatrix} \sum_{k=1}^{m} (h_k - N_k) \\ \sum_{k=1}^{m} s_k (h_k - N_k) \end{bmatrix} \tag{8}$$

With :
m: the number of used points
s: the distance of every point with regard to the same origin.
Pass 187 was fixed in order to eliminate the case of the parameter matrix singularity, considering its

stability and the quantity of measurements which it contains, we supposes that this pass does not contain orbit errors.

Table 4. Orbit errors

Pass number	Error (cm)
161	4.68
172	- 14.60
248	- 16.31
070	- 7.56
146	- 1.35
085	-7.77
009	4.75

With regards to used data quality and quantity, the error values obtained (in Table 4) can be considered acceptable. The average profiles, corrected by orbit errors, determined using a processing at the crossing points, and adjusted by means of a second order polynomial, represents the average heights of the sea surface under the satellite tracks.

6 Mean Sea Level Representation

The coating of average profiles corrected by orbit errors by a regular grid of 0.25° × 0.25 ° (in longitude and in latitude) allows to have the average surface.

This average surface was obtained by a linear interpolation method in the grid knot (Delaunay triangulation); excluding the regions, which were not observed by altimetry.

The mean sea level surface has an important dispersion (about 6 m, as shown by the Fig. 3) in the area of studies. This dispersion shows that several oceanographic phenomena caused an important variability of the level sea surface.

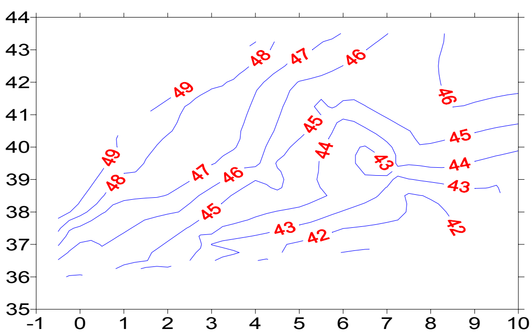

Fig. 3 Altimetric mean sea level by linear interpolation (in latitude and longitude).

7 Gravimetric Geoid Computation

Due to the rapid increase of GPS use heighting, which already now gives the same accuracy as levelling over some 10 to 100 km, there is an urgent need to provide the "cm quasi-geoid" to geodesists and surveyors. In this context, the Geodetic Laboratory of National Centre of Space Techniques has recently focused a part of the current research on the precise geoid determination using different methods. In 1997, the first determination of a preliminary geoid in a small zone in the north of Algeria was calculated using the least squares collocation and the Gravsoft software (Benahmed & al, 1997).

Nowadays, an improved quasi-geoid has been computed over the whole of Algeria between the limits $16° \leq \varphi \leq 40°$ for latitudes and $-10° \leq \lambda \leq 14°$ for longitudes, in a grid with mesh of 5'x 5'. This solution was based on the validated gravity data supplied by the Geophysical Exploration Technology Ltd (GETECH), topographic information's and optimal geopotential model, which were combined using the remove-restore technique in connection with the Fast Fourier Transformation (FFT).

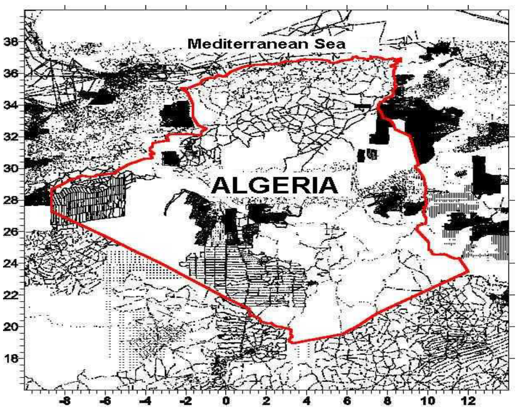

Fig. 4 Geographical distribution (latitude and longitude in degrees) of gravity measurements.

For this work, the pre-processed free air anomalies on a 5' grid in the area bounded by the limits mentioned above, derived by merging terrestrial gravity data and satellite altimetry data, have been provided by GETECH through the agreement between the National Centre of Space Techniques/Geodetic Laboratory and University of Leeds/GETECH without any information on the accuracy of different values. These data have been acquired in the framework of African Gravity

Project (AGP) from Bureau Gravimétrique International (BGI), Defence Mapping Agency and from oil companies and many national academic and non-academic organisations in different countries (Fairhead & al, 1988). All of these gravity measurements are adjusted at GETECH to IGSN71 by using "Latin American Gravity standardisation Net 1977" and are referred to the Geodetic Reference System 1980 (Blitzkow & al, 1995). Nevertheless, several data gaps still exist and new measurements are needed to accomplish a homogeneous coverage. The geographical distribution of the available gravity data, as shown in Fig. 4, presents some areas without measurements, particularly in the south country.

In order to smoothen the gravity field, the previous gridded gravity data must be corrected for the effect of the atmospheric and reduced for the effect of the spherical harmonic model and the topography. The spherical harmonic coefficient set OSU91A has been used to remove the long wavelength component of gravity data. The computation of the effects of topography according to the RTM reduction modelling method is based on global topographic model GLOBE of 30" x 30" which were used up to a distance of 200 km. The reference surface of 10' x 10' needed for the RTM reduction has been obtained by means of a moving average applied to the detailed one. Table 5 shows the statistics in mGals of the gravity reductions for the gravity data:

Table 5. Statistics of gravity reductions

Anomalies	Mean	Sd	Min.	Max.
Δg	2.43	28.81	- 172.96	218.84
$\Delta g - OSU91A$	-2.29	14.94	-122.90	192.28
$\Delta g - OUS91A - \mathrm{RTM}$	-1.55	14.62	-120.12	823.63

From the results of Table 5, it is obvious that the OSU91A reference field fits well the gravity in the area under consideration, and the smoothing of the gravity data is considerable after the removal of the topographic effect if we take into account only the mean and standard deviation values.

The residual quasi-geoid (ζ_r) has been evaluated using FFT technique, implemented in the GEOFOUR program written by Rene Forsberg (Tscherning, 1994). The statistics of residual undulations in a 5' x 5' grid (289 x 289 values) are presented in Table 5 while the plot of the values is shown in Fig. 5. As expected, high frequency pattern in gravity residual are spread on a larger area in terms of ζ_r; a careful outliers rejections will be performed in the near future to avoid such effects, probably connected to outliers or inconsistency in the gravity data (Barzaghi & al, 2001).

Table 6. Statistics of the quasi-geoid residuals ζ_r

Mean	Sd	Min.	Max.
0.00	1.42	-7.05	5.69

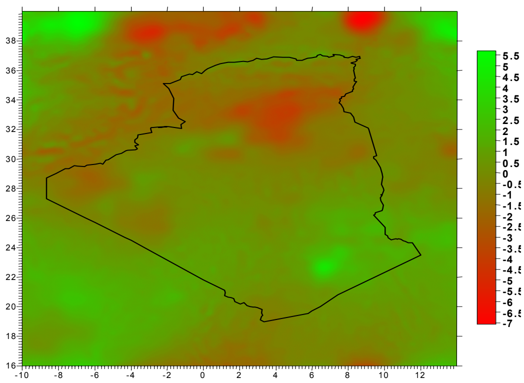

Fig. 5 Residual quasi-geoid (m)

The final quasi-geoid was obtained by adding the model and the residual terrain effect on the $5' \times 5'$ residual quasi-geoid grid. The values of the geopotential model range from 15.85 m to 56.0 m and yield the major part of the quasi-geoid. The standard deviation and maximum values of the contribution from the gravity data are 1.42 m and 5.69 respectively, while the corresponding values of the RTM effects are 0.07 m and 0.86 m.

Fig. 6 shows a map of the quasi-geoid solution in Algeria. The statistics of the total quasi-geoid values are summarised in Table 7.

The results presented above (Fig. 6) shows that the geoid undulation in Algeria, which is in the order of 40 m, present some stability along the Algerian coasts.

Table 7. Statistics of the quasi-geoid

Mean	Sd	Min.	Max.
35.18	8.83	17.69	60.65

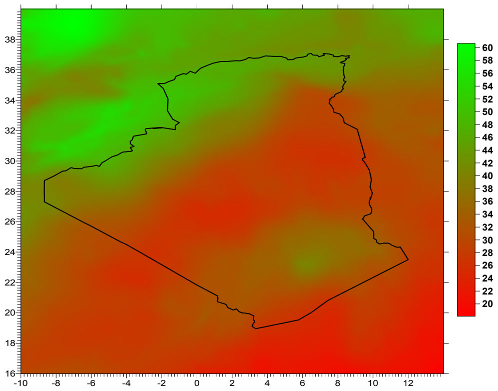

Fig. 6 Quasi-geoid solution in Algeria (m)

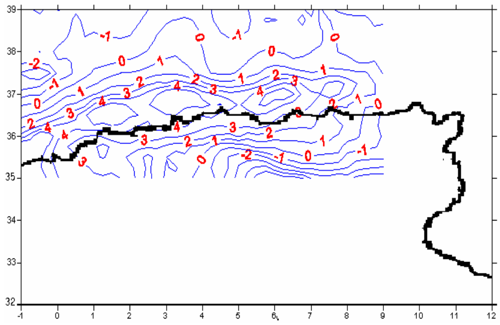

Fig. 7 Difference of heights (Kriging) (m)

8 Altimetric Position with Regard to the Geoid

Previous works on the occidental Mediterranean area were carried out (Kahlouche & al, 1998), and have led to compare an altimetric mean sea level, processed from non calibrated Topex data (1992), with a local geoid, computed only from the BGI gravity data. The metric differences (1 to 4 m) obtained do not allow to have definitive conclusions about the quality of the data used and the exhaustivity of the physical model processed. In this actual work, the altimetric solution is based on calibrated and recent (2000) Topex measurements to provide a mean sea surface on the west Mediterranean area.

To estimate the external quality of the obtained results, the altimetric solution was extrapolated and compared with the gravimetric geoid obtained by FFT technique and based, for the first time, on the GETECH data.

The comparison is made by processing the height differences on the same zone in the knots of the same regular grid (0.25° × 0.25 °) by Kriging's method which is based on statistical considerations; it was used to interpolate in all zones, even in regions without altimetric measurements. These differences are calculated in a zone limited with meridians -1° and 9° and parallels 35° and 39°, it includes the zones which were not observed by altimetry. The differences are carried in the sense of gravimetric geoid -mean surface, and with regard to the GRS80 reference ellipsoid. Differences between the two surfaces, showed by the Fig. 7, have an average of 2.2 m with a standard deviation of 1.3 m.

Off the Algerian coast, we note an east-west propagation deviation, probably due to marine disturbances at the east west Algerian current, in the outlines showed by Fig. 7.

The geographical distribution (latitude and longitude are expressed in degrees) of the level curves deducted from the subtraction of the two surfaces shows important values in the coastal zone. In this zone, as a boundary between the two mediums (terrestrial for gravity measurements and marine for the altimetric data), we expected initially minimum differences. Among the objectives of the study is to examine the possibility of providing an useful reference surface, as a marine geoid approximated by a mean sea level processed from altimetric data.

A first analysis of the obtained differences allows to confirm that they are due to several parameters as:

- The precision of the gravimetric geoid model obtained by FFT: considering the accuracy of the gravimetric data and their coverage and in absence of a high-resolution digital terrain model (DTM), the geoid processed is not very precise.
- The extrapolation method used: the extrapolation of the data from a physical environment towards an other one totally different, does not allow us to interpret the theoretical results.
- The quantity of altimetric data: data over a period more than three months of observations allow us to have a better precision on the processing of a mean sea level.
- The quality of the altimetric data used: the absence of corrective terms, such as tides, affects the precision of the mean surface processed.
- A more exhaustive modelling: to be able to make comparisons with gravimetric geoid notably, a more complete modelling should include for example a dynamic topography model, which must be subtracted from the mean sea surface obtained by altimetry.

9 Conclusion

The analysis of the results of altimetric measurements collected by Topex satellite on the western basin of the Mediterranean Sea can not be estimated completely for non-availability of all the corrective terms. The results are far to being perfect from an accuracy point of view; because of the quality and the quantity of used measurements.

The extrapolation method of the mean sea level on the North of Algeria does not allow us to have a reliable result because it is an extrapolation of a physical environment towards another completely different, but nevertheless this allowed us to estimate the degree of closeness of the two surfaces.

The reference surface of comparison (gravimetric geoid obtained by collocation on the North of Algeria) is also processed with some errors because of insufficiency of the gravimetric data, what makes difficult a strong comparison and analysis of the deviation. The analysis of the deviations obtained confirms the none adequacy of the method used; what for precise applications, makes necessary the availability of marine gravimetric data for the determination of the mean sea level.

In perspective, for the determination of the precise mean sea level, it is necessary to use Topex data, for longer duration, with a high quality, and the introduction of new measurements collected with other new altimetric systems as Jason. It is also necessary to define an exhaustive modelling taking into account all the corrective terms and all new existing data (tide gauge data, levelling, Algerian absolute gravity network,…).

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References

Aviso user handbook (1996). Merged TOPEX/POSEIDON Products (GDR-Ms), AVI-NT-02-101-CN, edition 3.3-1996.

Barzaghi, R., and F. Sanso (1992). Altimetry Rankdeficiency in Crossover Adjustment, Manuscripta geodaetica.

Barzaghi, R., A. Borghi and F. Sanso (2001). Quasi Geoid Estimations in South America, IGeS Bulletin No. 11, ISSN 1128-3955.

Benahmed Daho, S. A. (2000). The New Gravimetric Geoid in Algeria, IGeS Bulletin No.10, ISSN 1128-3955, pp. 85-90.

Benahmed Daho, S. A., and S. Kahlouche (1998). The Gravimetric Geoid in Algeria: First Results, International Association of Geodesy Symposia- Geodesy on the Move Vol. 119, pp. 262-268, ISBN 3-540-64605, Springer Verlag Editor.

Bonnefond, P. (1994). Méthode Géométrique De trajectographie Par Arcs Courts, Application a L'Analyse Des Mesures Altimétriques Du Satellite TOPEX-POSEIDON Et ERS-1 En Méditerranée. Doctoral Thesis, CERGA.

Bonnefond, P., P. Exertier and F. Barlier (1996). Suivre L'Évolution Du Nveau Moyen De La Méditerranée. Bulletin of the French Society of Photogrammetry and Remote Sensing, No. 143.

Cristensen, E. J., and A. Menard (1994). Observation of Geographically Correlated Errors for TOPEX-POSEIDON Using the Global Positioning System, Géophys Res Lett.

Degnan, J. J. (1993). Milimeter Accuracy Satellite Laser Ranging, a Review, Contribution of Space Geodesy to Geodynamics: Technology, Geodynamics Series.

Engelis, T. (1987). Radial Orbit Error Reduction and Sea Surface Topography Determination Using Satellite Altimetry, Report No. 377.

Fairhead, J. D., A. B. Watts, P. Chevalier, B. E. Haddadeh, C. M. Green, G. W. Stuart, K. A. Whaler and I. Whibdle (1998). African Gravity Project. Technical Report, University of Leeds Industrial Services Ltd.

Kariche, M. I. (1997). Traitement Des Données Altimétriques Du Satellite TOPEX-POSEIDON: Comparaison Avec Un Modèle Global. Master Thesis - CNTS Algeria .

Kahlouche, S., M. I. Kariche and S. A. Benhamed Daho (1998). Comparison between Altimetric and Gravimetric Geoid in the South-West Mediterranean Basin, International Association of Geodesy Symposia, Geodesy on the Move Vol. 119, pp. 281-287, ISBN 3-540-64605, Springer Verlag Editor.

Lettre du CNES NO.139, Lancement de TOPEX/POSEIDON. (1992).

Moritz, H. (1989). Advanced Physical Geodesy, Second Edition, Wichmann, ISBN 3-87907-195-0.

Rummel, R. (1993). Satellite Altimetry in Geodesy and Oceanography, Lecture Notes in Earth Sciences, 50, Springer-Verlag, pp. 453-466.

Rapp, R. H., and F. Sanso (1995). Determination of the Geoid Present and Future, International Association of Geodesy Symposia, No. 106.

Stewart, R. H. (1985). Methods of Satellite Oeanography, University of California Press, ISBN 0-520-04226-3.

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.

Zarouati, O. (1987). Trajectoires Spatiales, Cepadues Edition, ISBN 2.85428.166.7, No. 190.