920

A Comparison between SEASAT, GEOSAT and Gravimetric Geoids Computed by FFT and Collocation in the Central Mediterranean Sea

R. Barzaghi*, R. Forsberg** and C.C. Tscherning**
* Politecnico di Milano, Milano, Italy
** Geodetic Institute, Charlottenlund, Denmark

Abstract

Gravimetric geoids have been computed for the central Mediterranean Sea between latitude 32° and 36° and longitude 18° and 22° using FFT and collocation. A comparison with cross-over adjusted SEASAT and GEOSAT data in the area showed for both gravimetric geoids the standard deviation of the differences to be 0.20 m and 0.15 m, respectively. The mean and standard deviation of the difference between the FFT and the collocation geoid heights were -0.82 and 0.20 m, respectively. This quite large difference may be due to the different data sampling and noise weighting used by the two methods, but is not yet fully explained.

1. Introduction

In the early 1990'ties the ERS-1 and the Topex/Poseidon satellites will be launched, both equipped with a radar altimeter. The usefulness of the altimeter data for oceanographic purposes will be greatly improved, if we are able to compute a precise height reference surface for an area being investigated, i.e. a regional, relative, geoid. By this we mean that height differences are precisely known, but that all the values may be affected by a common bias. (Clearly, it would be better, if we could compute an absolute geoid, but this will require that e.g. a global gradiometric satellite mission is carried through).

At the Geodetic Institute there has been developed a software package for gravity field modelling "GRAVSOFT", which may be, and have been, used for geoid determination (Tscherning and Forsberg, 1986). The package includes programs for gravity modelling using collocation, (GEOCOL), and FFT (GEOFOUR), as well as programs for the estimation of statistical parameters for the gravity field (EMPCOV, COVFIT).

It is our intension to use GRAVSOFT for geoid determination as a part of our participation in the ESA ERS-1 project. Therefore we wanted to test the programs in a kind of worst-case situation, namely where the geoid variation was large. On the other hand, the distribution of the gravity data should be good, and nearly no oceanographic phenomena should influence the satellite altimeter data, which we wanted to use in our evaluation. Such a situation is found in the central Mediterranean Sea, see Fig. 1.

In the following we will describe the data and the result of the evaluation.

Presented Chapman Conference on Progress in the Determination of the Earth's Gravity Field, Ft. Lauderdale, Florida, SEP 13-16, 1988.

2. Available Data

Gravity data were made available to us by D. Arabelos, University of Thessaloniki, in the form of data in a 0.125^{0} grid digitized from the maps published by Morelli et al.(1975). Data in the sea area shown in Fig. 1 was used.

Since the use of the FFT requires data to be available in a regular grid all the missing values were predicted using a fast collocation procedure implemented in the program module GEOGRID. On the other hand does collocation not permit the use of all the 4194 values, since a full system of equations with this dimension must be solved. Therefore, when using collocation for geoid computation, only the 0.25^{0} grid points were used outside the 4^{0} x4^{0} inner area, where the geoid was computed.

Cross-over adjusted SEASAT-data (Cruz and Rapp, 1982) were made available to us by R.H. Rapp. A local cross-over adjustment, using the data in the 4^{0}x4^{0} area, made the standard deviation of the cross-over values of the six used tracks decrease from 0.05 cm to 0.02 cm. Raw GEOSAT data were also adjusted, and cross errors (mainly due to data over land, see Fig. 1) were removed. The data covered a 1/2 year period, and contained therefore up to 10 repeat tracks. Originally the dataset consisted of 3096 points, which before the removal of gross errors had a standard deviation of 5.53, and with 97 values removed had a standard deviation of 2.87 m. The result of a cross-over adjustment with only bias gave a standard deviation of the cross-over differences of 0.05 m compared to 5.29 m before the adjustment.

3. Gravimetric Geoid Computations

First the contribution of the spherical harmonic expansion GPM2 was subtracted. Using these "reduced" values, empirical auto- and cross -covariance functions were estimated by EMPCOV, using the gravity and the GEOSAT data, regarded as geoid heights. An analytic expression for the covariance function was then determined using COVFIT (Knudsen,1987),

$$C(\psi) = a\cdot \sum_{i=o}^{N} e_i \, P_i(\cos\psi) + \sum_{i=N+1}^{\infty} \frac{A(i-1)}{(i-2)(i+4)} \left(\frac{R_B}{R}\right)^{2i+4} P_i(\cos\psi).$$

Here ψ is the spherical distance between two gravity anomaly values (at the sea surface), e_i the error degree-variances of GPM2, a, A scale factors and R_B the radius of the so-called Bjerhammar sphere. R is the mean radius of the Earth, and P_i are the Legendre polynomials. Values of N-120, a-0.88, A-444 and R-R_B=3.75 km was found to give a nearly perfect agreement between the analytic expression and the empirical auto- and cross covariances.

The gravity data were then used to compute geoid heights for the 4^{0}x4^{0} area. The use of collocation look more than 10 times as long time as the use of FFT. A comparison with the altimeter measurements were then made, and the results are given in Table 1. In Fig. 2 are shown the FFT, collocation and GEOSAT heights along the longest track in the open sea.

Table 1. Comparison of FFT and collocation gravimetric geoids with SEASAT and GEOSAT adjusted altimeter heights.

	Mean m	Standard Dev. m
GEOSAT-data with GPM2 subtracted	-1.24	0.62
Difference GEOSAT-FFT geoid	-2.18	0.15
Difference GEOSAT-Collocation geoid	-1.37	0.15
Difference SEASAT-FFT geoid	-0.54	0.20
Difference FFT-Collocation geoid	-0.82	0.20

The difference between the FFT and collocation geoid heights are shown in Fig. 3. The large mean difference and standard deviation may be caused by the way the two methods accounts for the long-wavelength information. Also the standard deviation of the differences is surprisingly large, considering that both methods agree so well with the GEOSAT data.

A detailed analysis of the differences between the GEOSAT heights and the gravimetric geoid heights along the individual tracks, see Fig. 4, showed that altimeter data close to the coast (<50 km distance) have a larger variation than points at the open sea. This indicates a possible coastal current, the existence of which must be verified.

4. Conclusion

The result of the investigation shows (as expected) that the GEOSAT data in this area are slightly superior to the SEASAT data. Also, considering the error in the altimeter data, we have demonstrated that it is possible to compute a regional, relative geoid, at the decimeter level, using the GRAVSOFT programs. It is obvious, that FFT should be used if the data configuration and quality permits it. Otherwise collocation should be used, since it puts few requirements on the data configuration, and also makes it possible to include the adjusted altimeter data as observations. The quite large differences between FFT and collocation must be further studied.

Acknowledgement: This report is a contribution to a project supported by European Community contract no. St2J-39-DK(EDB).

References

Cruz, J.Y. and R.H.Rapp: Sea surface heights in the Mediterranean area from SEASAT altimeter data. Bollettino di Geofisica, Vol. 24, no. 95, pp. 167-174, 1982.

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

Morelli, C., M. Pisani and C. Gantar: Geophysical Studies in the Aegean Sea and in the Eastern Mediterranean. Bollettino di Geofisica teoretica ed applicata, Vol. XVIII, pp. 127-168, 1975.

Tscherning,C.C. and R.Forsberg: Geoid determination in the Nordic Countries - a status report. Proc. 10. General Meeting of the Nordic Geodetic Commission, Helsinki, 29.-sept.-3.oct.1986, pp. 279-290. Published by Finnish Geodetic Institute, 1986.

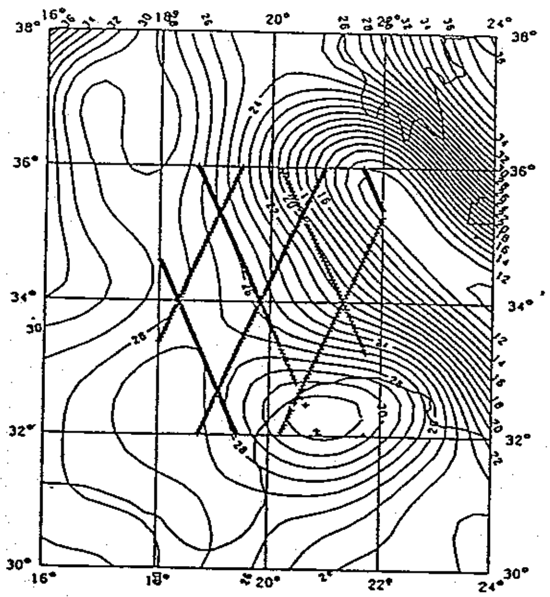

Fig. 1. Geoid heights (contour interval 1 m) derived from GPM2 with the used GEOSAT tracks.

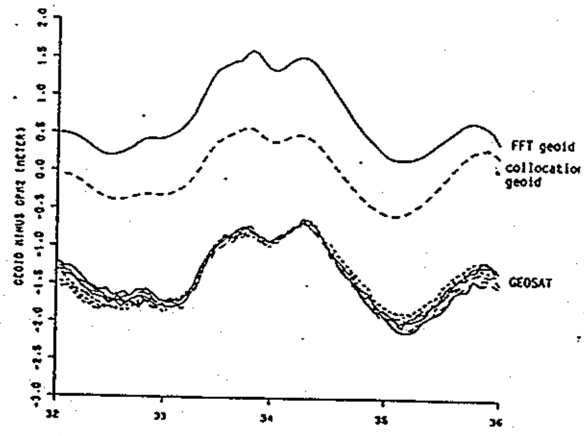

Fig. 2. Adjusted GEOSAT heights and corresponding FFT and collocation geoid heights along the longest track. The contribution from GPM2 is subtracted.

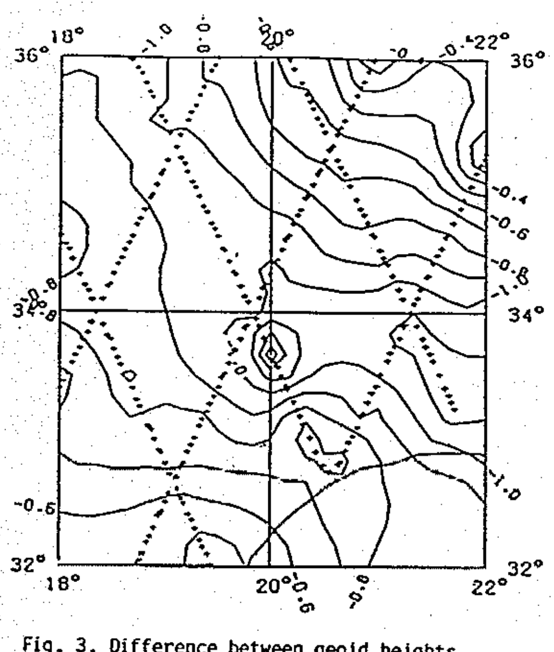

Fig. 3. Difference between geoid heights computed by FFT and collocation. Contour interval 0.1 m.

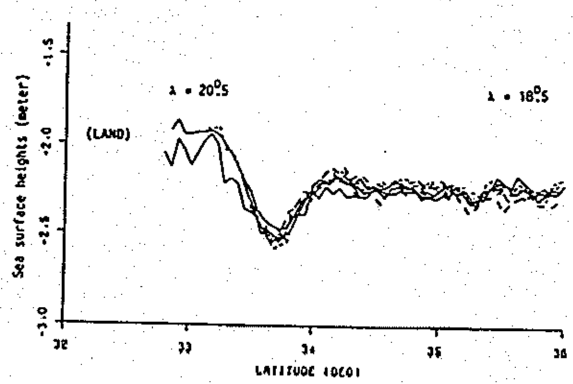

Fig. 4. Sea-surface heights computed as the difference between the GEOSAT heights and the gravimetric geoid heights computed by FFT.