Summary of presentation

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Report

Norsk Hydro R&D Project

"Radar Altimetry"

by

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The purpose of the project:

Improve the use of satellite altimeter data for gravity field determination and

Study the inverse gravimetric problem.

Duration: 3 years.

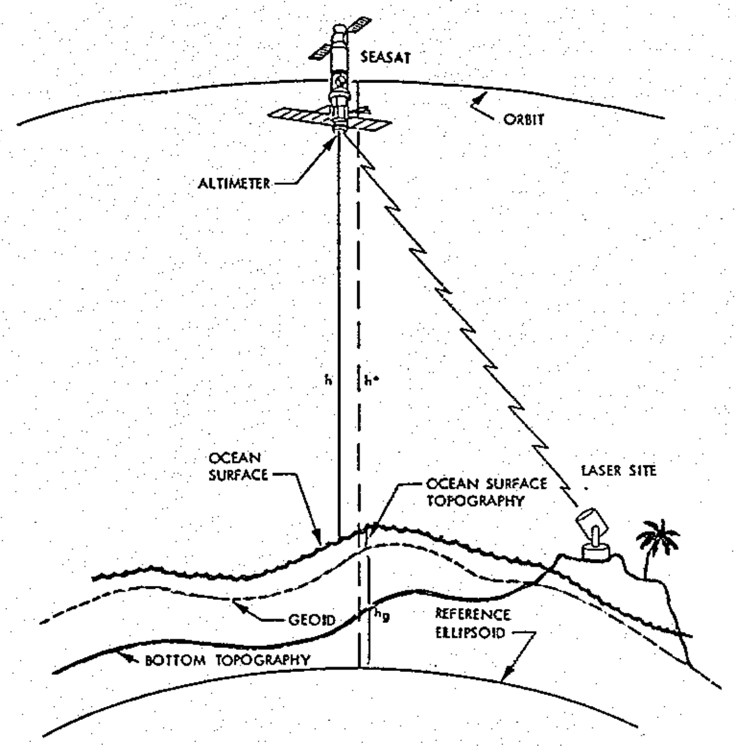
Outcome: 15 papers/reports.

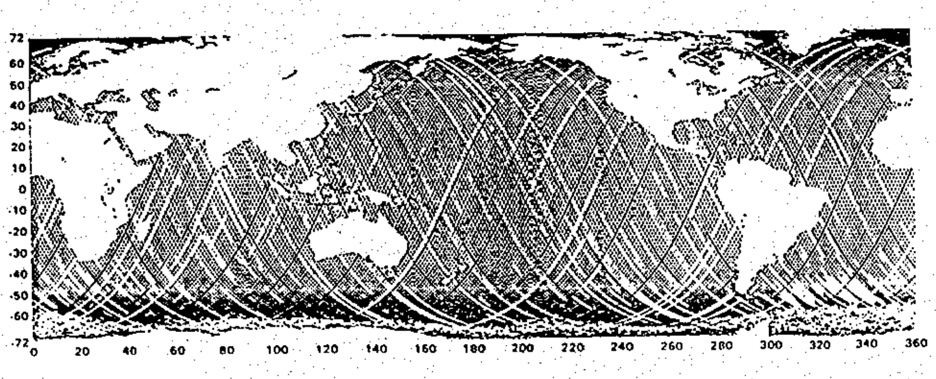
This report: A summary.

Comment: The project was carried out at Kort- og Matrikelstyrelsen (KMS or National Survey and Cadastre), Geodetic-Seismic Division, Rentemestervej 8, DK-2400 Copenhagen NV. The division is the former research department at the Geodetic Institute and has a long tradition for doing research in gravity field determination.

Next page: Figures showing the principle of measuring the sea surface height from satellite by radar altimetry, the ground track pattern of the measurements, and some examples of geoid/-gravity anomalies generated from density anomalies.

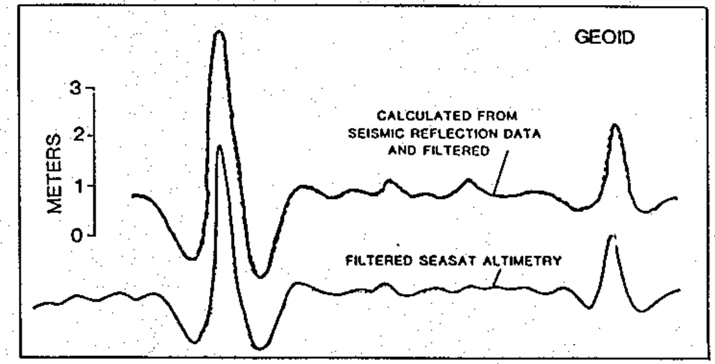
Måling af havoverfladens højde over ellipsoiden fra satellit:

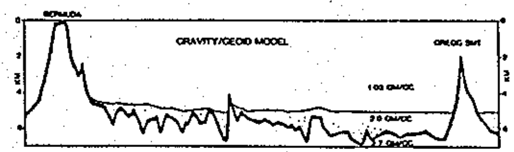


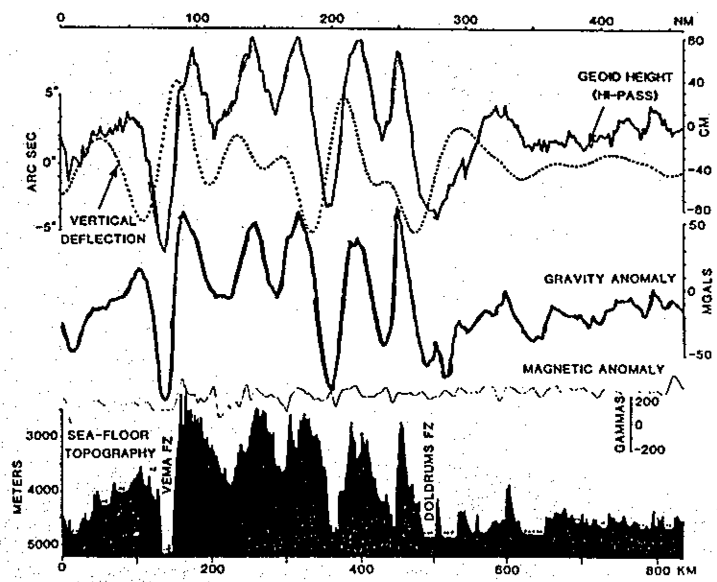


Seasat Altimetry, the North Atlantic Geoid, and Evaluation by Shipborne Subsatellite Profiles

P. R. Vogt et al.







The altimetric observation:

SSH = N + SST + e

Geodetic estimation techniques can convert geoid heights into gravity anomalies.

However, the altimeter data contain errors and oceanographic signals!

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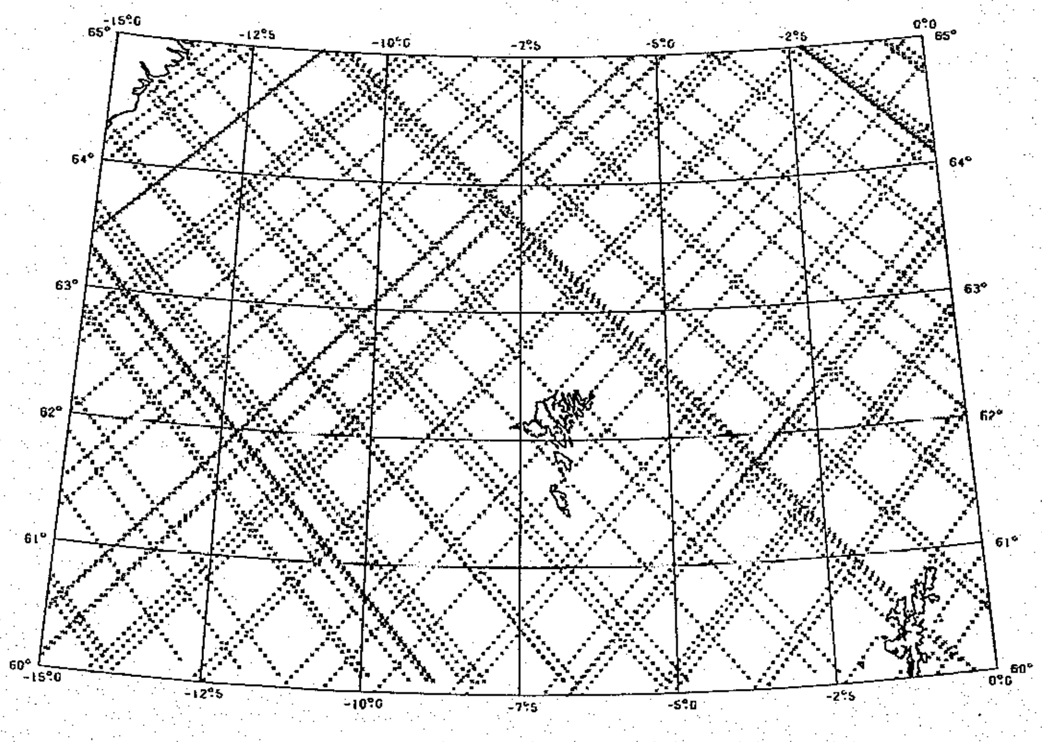
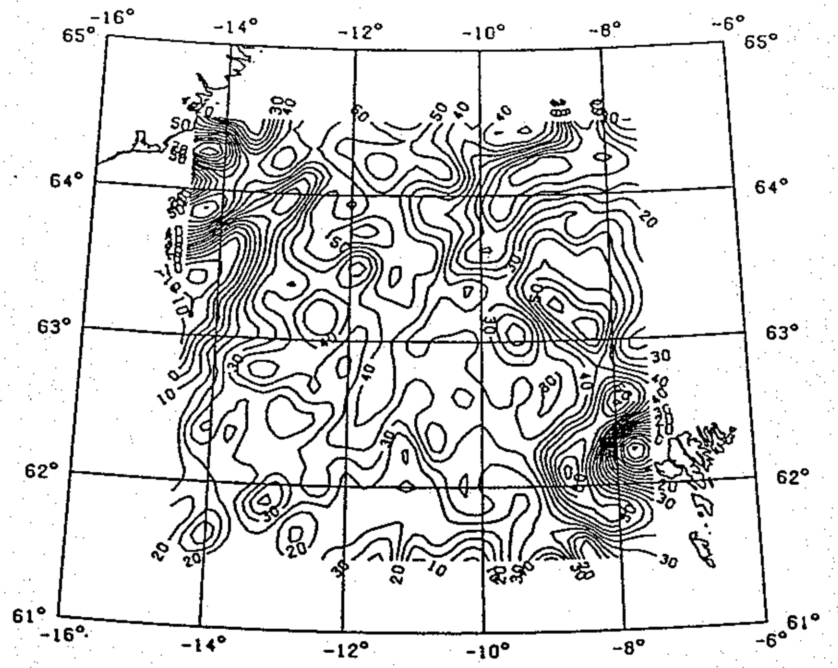
Prior to this research the altimeter data were pre-adjusted in a cross-over adjustment.

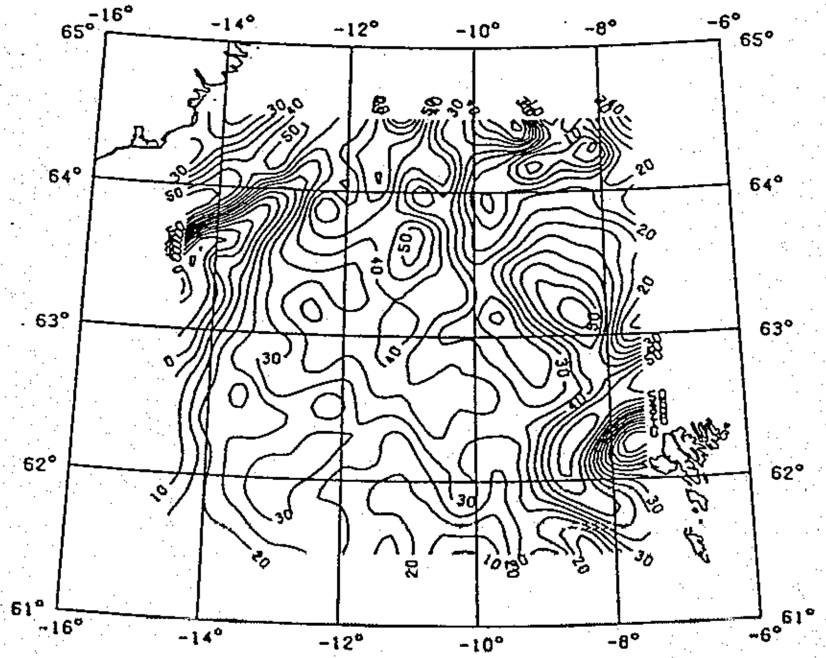
Here an accuracy of about 7 mgal was ashieved in the Faeroe Islands region:



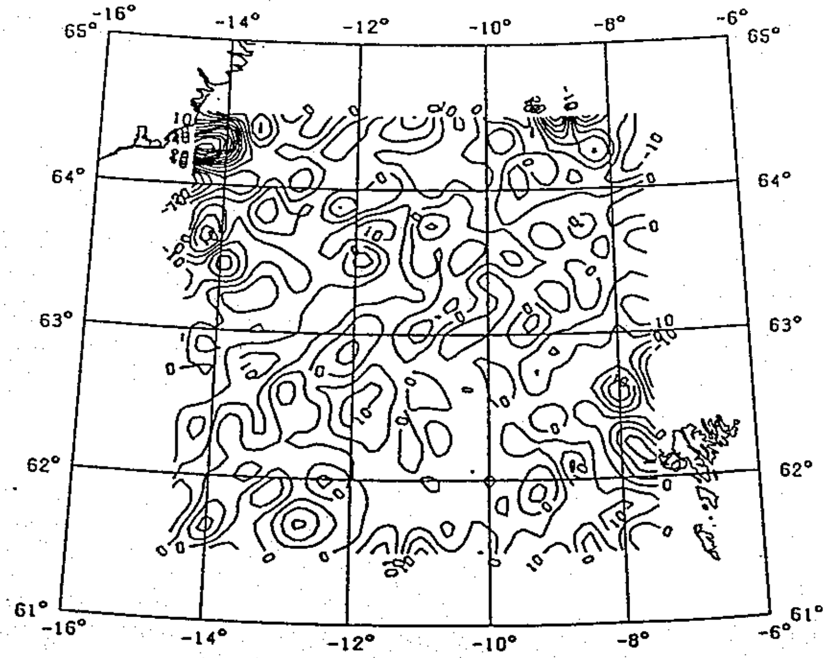
Location of all SEASAT altimeter data.



Free-air gravity anomalies estimated from adjusted SEASAT altimeter data. C.I. 5 mgal.



Free-air gravity anomalies estimated from gravity observations. C.I. 5 mgal.



Differences between altimetric and gravimetric free-air anomalies. C.I. 5 mgal.

Comment: The results from the Faeroe Islands region have shown that gravity anomalies successfully can be estimated from satellite altimetry. However, some residual errors from the cross-over adjustment and gross errors in the altimetry need further treatments. Hence:

The improvement of the use of satellite altimetry is established through:

a) Improve treatment (removal) of correlated errors in the satellite orbit and sea surface height variations and

b) Improve exploitation of auxiliary informations:

1. Marine gravimetry,
2. Bottom topography,
3. Tide gauge, and
4. Ocean current data.

Goal: To derive high accuracy gravity anomalies in local regions (e < 5 mgal).

During the research a method was developed that simultaneously can estimate:

a) The gravity field,
b) The sea surface topography, and
c) The altimetric errors

from a combination of:

1. Satellite altimetry,
2. Marine gravimetry,
3. Tide gauge, and
4. Ocean current data.

Informations about the bottom topography can be utilized in an initial reduction of the data in order to decrease the magnitude of the unknown gravity field.

Comment: The estimation method that has been developed, has the advantage that all signals/errors in the altimetry are modelled simultaneously using their respective characteristic magnitudes and wavelength contents. Hence the needs of cross-over adjustments are eliminated. Furthermore proper error estimates and error correlations can be obtained in order to evaluate the results and the performance of satellite altimetry.

Validation:

The estimation method was tested using SEASAT altimetry in the Nordic region by an evaluation of:

1. Formal error and error correlation estimates,
2. Agreements with marine gravimetry, and
3. Power spectral densities.

Furthermore, the information content of each type of auxiliary informations was evaluated.

Results:

The estimation of gravity anomalies from satellite altimetry alone has been improved.

Now an agreement of 2-3 mgal is obtained.

At wavelengths longer than 40 km the agreement is much better.

An optimal product is obtained, when altimetry and marine gravimetry are used simultaneously.

The resolution of the available bottom topography data is too poor to improve the results.

The information from tide gauges and the knowledge about the ocean currents is much too poor.

Comment: The accuracy and the resolution of the gravity anomalies estimated from altimetry alone are highly dependant on the data coverage, which is highly latitude dependant. Hence, the highest accuracies are obtained in areas close to 72^{o} latitude. The along track resolution of Seasat altimetry has been reported to be around 32 km in wavelength, which may be ashieved as a 2D resolution at high latitudes, where our 2-3 mgal agreement was obtained. The newer satellite GEOSAT has provided repeat data for almost four years. Using these data and a new processing and stacking method a resolution of 12 km has been obtained at the National Geodetic Survey, USA.

Question: How are your products as compared with Petroscan AB's?

Answer: Originally Petroscan AB produced high-pass filtered geoid anomaly maps. They showed a clear correlation between their low values and oil producing fields. This correlation is simply due to the fact that oil <u>may be found</u> in sediments having a low density. During the past years their products have improved. Now they convert the geoid into gravity anomalies, as we have done all the time, since geoid anomalies are hard to interpretate as compared with gravity anomalies. Still they apply the cross-over adjustment (Hayling, Petroscan AB, pers. comm.), as we did before, so they cannot obtain an optimal product and provide a proper accuracy analysis.

The inverse gravimetric problem is studied with respect to:

a) Choice of base functions,
b) Introduction of a-priori information,
c) Analysis of well log data, information,
and
d) Test and update traditional methods for gravimetric inversion.

Comment: The inverse gravimetric problem described the problem of estimating the density distribution in the earth from gravity data. During this project some basic problems have been treated. First of all, it has been evaluated how the density distribution should be described in terms of mathematics. Furthermore, it should be possible to take a-priori informations and correlations into account in the inversion. This is important, since we know that density or depths to an interface are correlation in nature. Such correlations may be studied using well log data. Furthermore the traditional methods for gravimetric inversions have been studied and tested in order to understand how the gravimetric inversion has been applied.

An experiment of non-linear inversion of gravity data in the Horn Graben area, North Sea:

Observations:

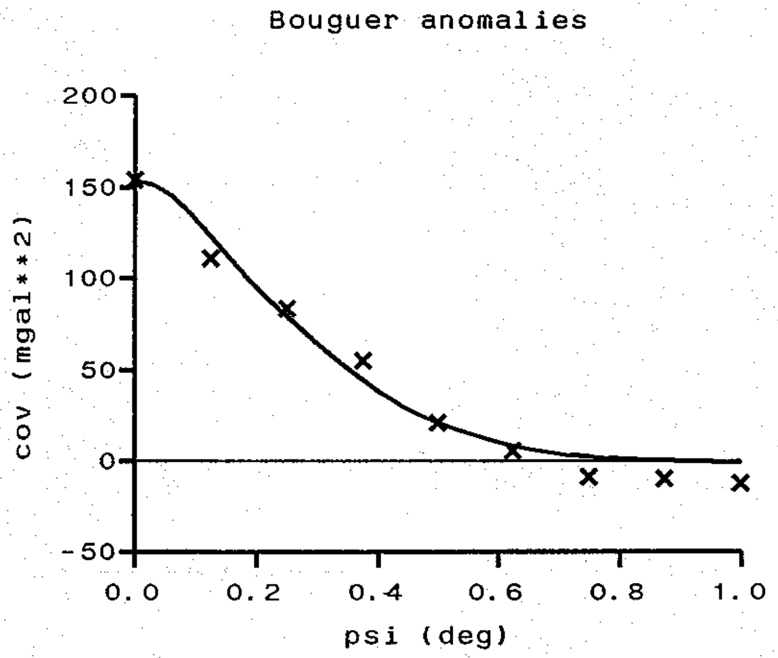
Mean bouguer anomalies

Model:

$1/8^{o}$x$1/4^{o}$ blocks
Fixed bathymetry
Sediments/Crust
Crust/Mantle (MOHO)

Comment: In this experiment the traditional inversion is tested. However, the method has been updated, so a-priori values and correlations can be taken into account through the use of constraints.

Constraints for: A-priori values, Isostasy, and Correlations.

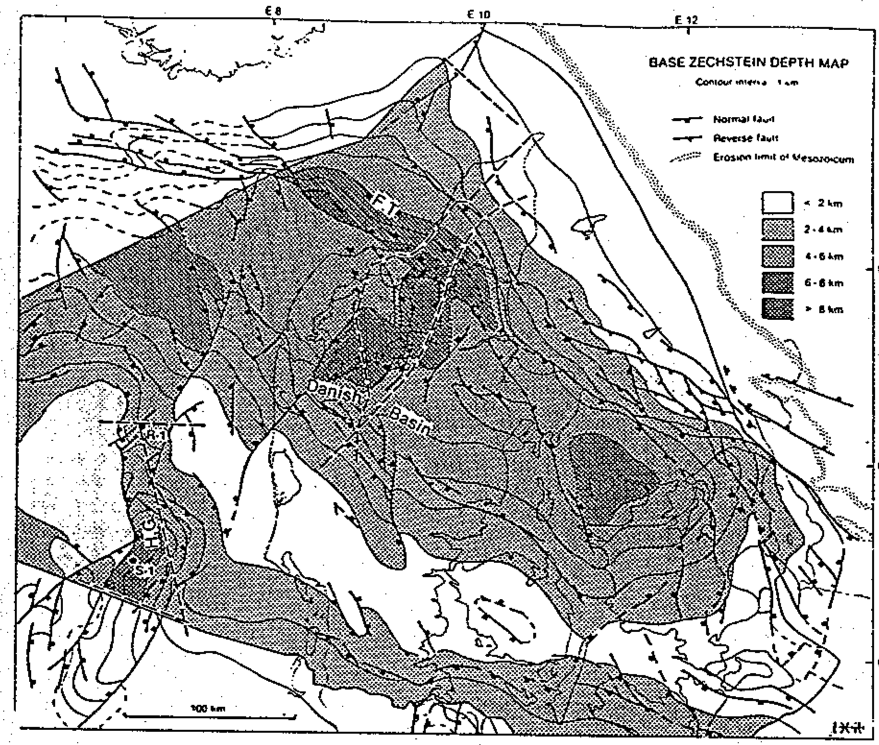


Covarince functions from observations (x) and and a-priori correlations as implied by the constraints applied on the model.

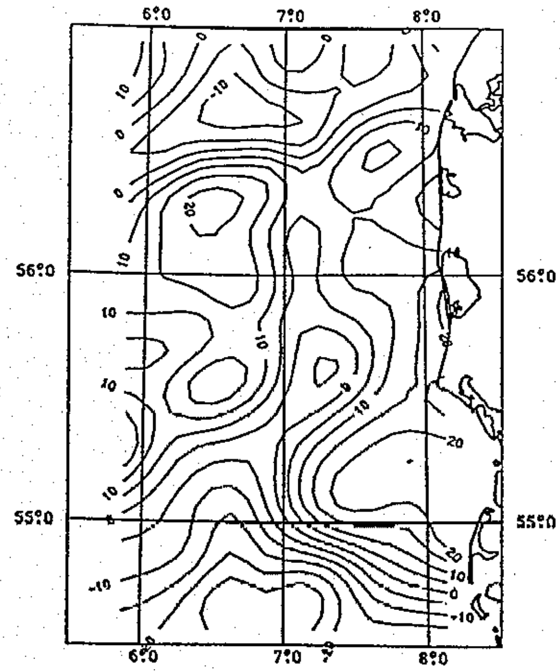
Expectations:

Fully compensated, long wavelength structures can not be estimated from gravimetry, but short wavelength structures may be estimated.

Comment: Note that the constraints have the determined, so the a-priori assumptions about the statistics of the model is in agreement with the statistics that is observed on the surface with the observations. Also note the 50% correlation distance of 0.33^{o} or 36 km.

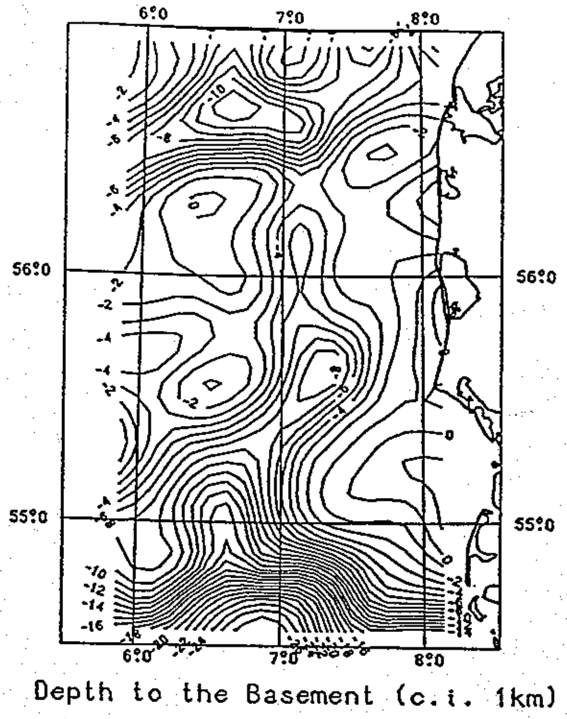


The base of Zechstein/top of Rotliegende (from Vejbæk (1990), fig.3)

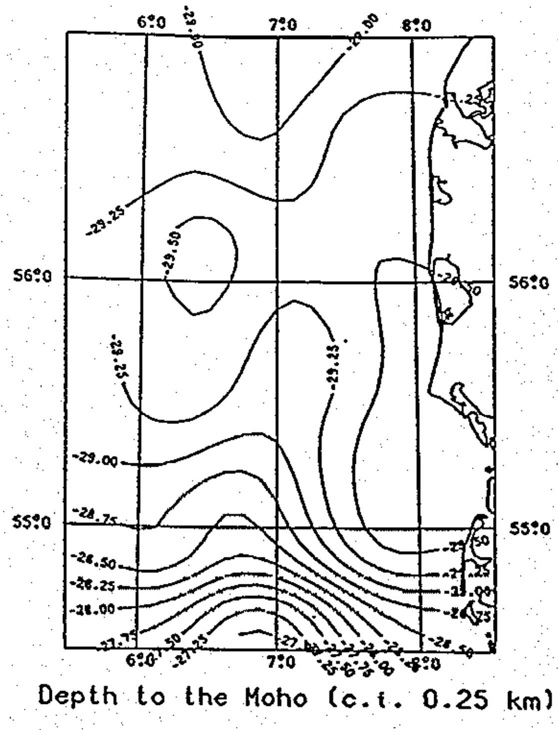


Bouguer Anomalies (c.i. 5mgal)

The bouguer anomalies from gravimetry and altimetry. Contour interval: 5 mgal.



The topography of the upper interface (the basement). The solution obtained for the problem with two discontinuity surfaces. Contour interval: 1 km.



The topography of the lower interface (the Moho). The solution obtained for the problem with two discontinuity surfaces.

Results:

A method for inversion of gravity data has been developed.

A-priori informations and correlations can be taken into account trhough the use of constraints.

The results obtained in the Horn graben area are promising.

Future aspects:

Use a more complex model.

Use seismic results directly.

Conclusions:

The use of satellite altimetry for gravity field determination has been improved.

The altimetry is found to be a valuable source of regional information.

The inverse gravimetric problem has been studied and promising results have been obtained.

A valuable contact between Norsk Hydro, Bergen, and KMS has been established

Computer programs and routines are installed in Bergen, also ready for new ERS-1 altimetry.

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