INVESTIGATE THE TIME EVOLUTION OF THE CORRELATION BETWEEN BATHYMETRY AND THE GEOID HEIGHT IN THE PACIFIC OCEAN

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Final Report
For the period 31 July 1979 through 31 July 1981

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The SEASAT radar altimeter data were received in two phases: the first set of data, which consisted of repetitive passes in selected areas of the Northern hemisphere, was received in the Fall of 1979.

A second set of data which consisted of the complete geophysical data set was received in the Spring of 1981. Because of the delay in receiving a complete set, we supplemented the initial SEASAT data set with the less accurate, but complete, GEOS-3 data set, during the first 18 months of this contract.

We have first organized and catalogued the initial data set by increasing revolution number. The Hawaiian region in the Pacific Ocean has been chosen as a test area; an extensive study of that area has been done using the GEOS-3 radar altimetry data and has given excellent results (Roufosse, M. C., Parsons, B. E., EOS Trans., AGU, 58, 1213, 1977). Ninety SEASAT passes have been retrieved, plotted and edited in that region in order to assess the gain in accuracy offered by SEASAT over GEOS radar altimetry data. The noise level is at least 5 times smaller for the SEASAT radar altimeter than it is for GEOS-3. This can be seen in Figure 1, which represents a comparison between the SEASAT and GEOS-3 data over the Hawaiian Seamount after editing of both data sets.

The method used to explain the shape and intensity of the geoid signal was described in the proposal for this contract (P940-1-80) and shall be summarized here. The lithosphere is considered as a thin elastic plate which deforms when it is loaded by bathymetric features such as seamounts. The study of the correlation existing between the geoid heights and the bathymetry yields information on the mechanical properties of the plate. These mechanical properties will be dependent upon the thickness and thus the age of the lithosphere.

Practically, following the rationale developed by McKenzie and Bowin (Journ. Geophys. Res., 81, 1903, 1976), we have calculated a series of filters in wave number space with a variable value for the flexural rigidity. These filters are of the form

$$Z(k) = \frac{3(p_c - p_w)}{2rp_e\gamma} \frac{(1 - e^{-wkt})\, e^{-wkd}}{[1 + (wk)^4]\, wk}$$

where

$$\gamma = \left[\frac{(p_m - p_c)\, g}{F}\right]^{1/4}$$

$$w = \frac{2\pi}{n\Delta\gamma}$$

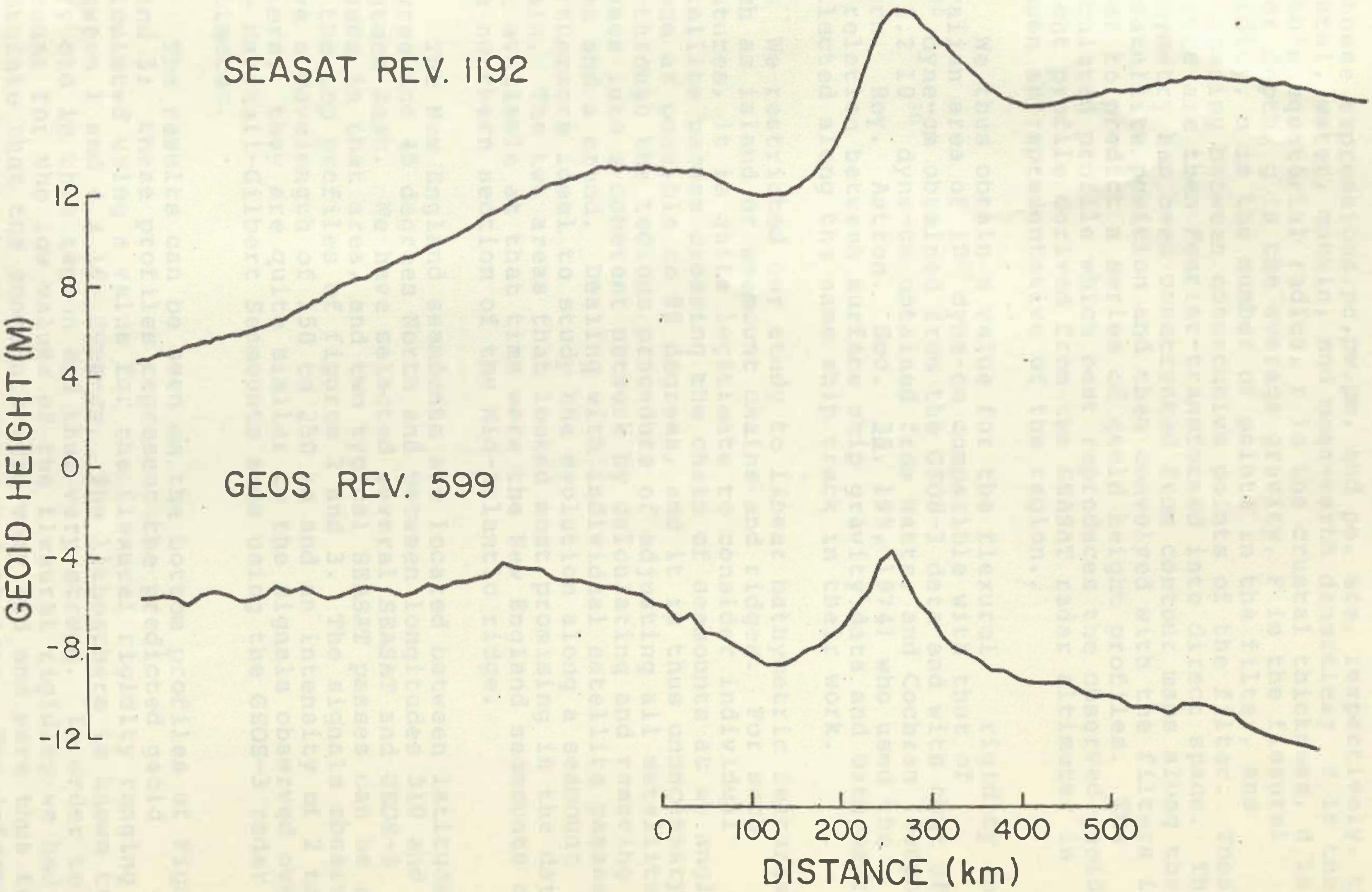


Figure 1. Comparison of geoid height over the Hawaiian Seamount chain (Geos 3 and Seasat Data).

In these expressions,pc,pw,pm, and pe, are, respectively, the crustal, water, mantle, and mean-earth densities; r is the earth's equatorial radius, t is the crustal thickness, d is the water depth, g is the average gravity, F is the flexural rigidity, n is the number of points in the filter, and is the spacing between consecutive points of the filter. These filters are then Fourier-transformed into direct space. The bathymetry has been constructed from contour maps along the subsatellite position and then convolved with the filters in order to predict a series of geoid height profiles. The calculated profile which best reproduces the observed geoid height profile derived from the SEASAT radar altimeter is chosen as representative of the region..

We thus obtain a value for the flexural rigidity in the Hawaiian area of 10^{30} dyne-cm compatible with that of 10^{30} dyne-cm obtained from the GEOS-3 data and with that of 0.8 to 1.2 10^{30} dyne-cm obtained from Watts, and Cochran (Geophys. Journ. Roy. Astron. Soc. <u>38</u>, 199, 1974) who used the correlation between surface ship gravity data and bathymetry collected along the same ship track in their work.

We restricted our study to linear bathymetric features such as island or seamount chains and ridges. For such features, it is quite legitimate to consider individual satellite passes crossing the chain of seamounts at an angle as close as possible to 90 degrees, and it is thus unnecessary to go through the tedious procedure of adjusting all satellite passes into a coherent network by calculating and removing a bias and a trend. Dealing with individual satellite passes is furthermore ideal to study the evolution along a seamount chain. The two areas that looked most promising in the data set available at that time were the New England seamounts and the northern section of the Mid-Atlantic ridge.

The New England seamounts are located between latitudes 35 degree and 45 degrees North and between longitudes 310 and 320 degrees East. We have selected several SEASAT and GEOS-3 passes in that area, and two typical SEASAT passes can be seen on the top profiles of figures 2 and 3. The signals observed have a wavelength of 150 to 250 km and an intensity of 2 to 3 meters; they are quite similar to the signals observed over the Marshall-Gilbert Seamounts area using the GEOS-3 radar altimeter.

The results can be seen on the bottom profiles of Figures 2 and 3; these profiles represent the predicted geoid calculated using a value for the flexural rigidity ranging between 1 and 4 x 10 dyne-cm. The lithosphere is known to be very old in this region and thus very strong. In order to account for the low values of the flexural rigidity we had to postulate that the seamounts were very old and were thus formed where the lithosphere was younger and thinner. The information

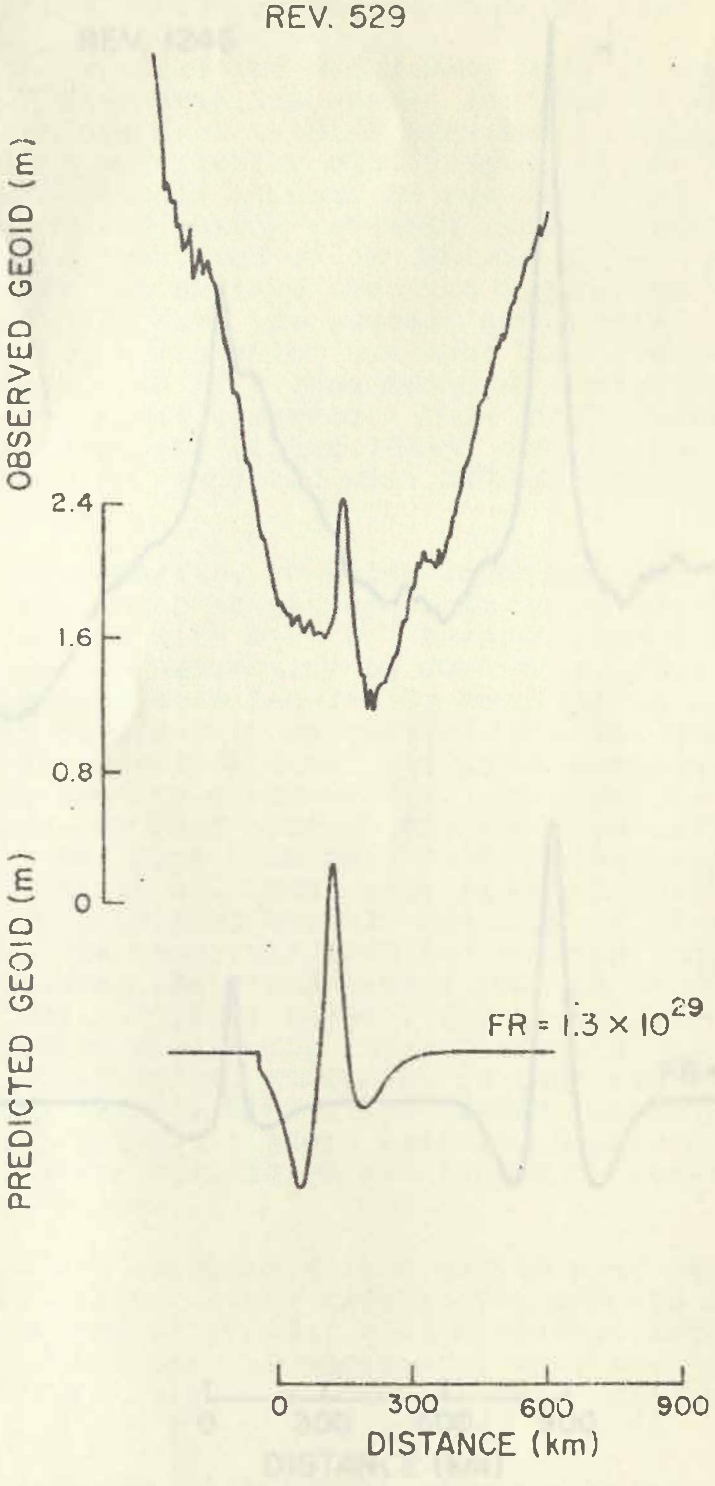


Figure 2 The top profile represents the observed geoid heights for the Seasat revolution number 529 over the New England seamounts. The bottom profile represents the predicted geoid heights calculated with a value for the flexural rigidity of 1.3 × 10^{29} dyne-cm.

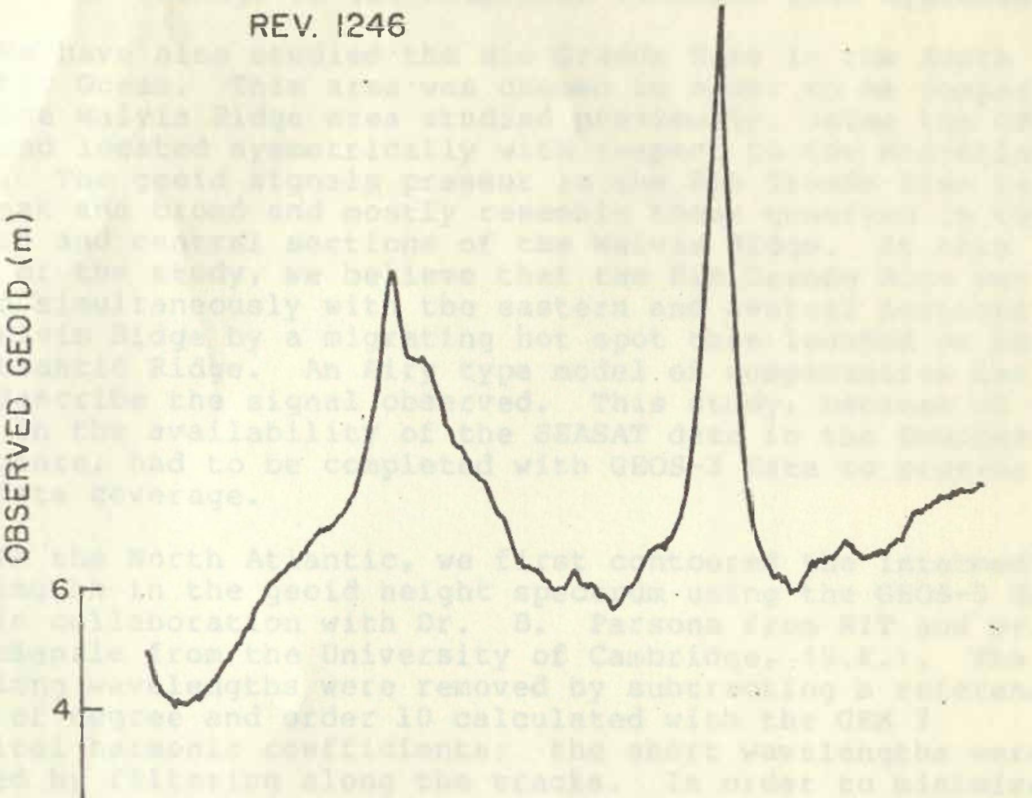


Figure 3 The top profile represents the observed residual geoid heights for the Seasat revolution number 1246 over the New England seamounts. The bottom profile represents the predicted geoid heights calculated with a value for the flexural rigidity of 3×10^{29} dyne-cm.

gathered on the age of the seamounts confirms that hypothesis.

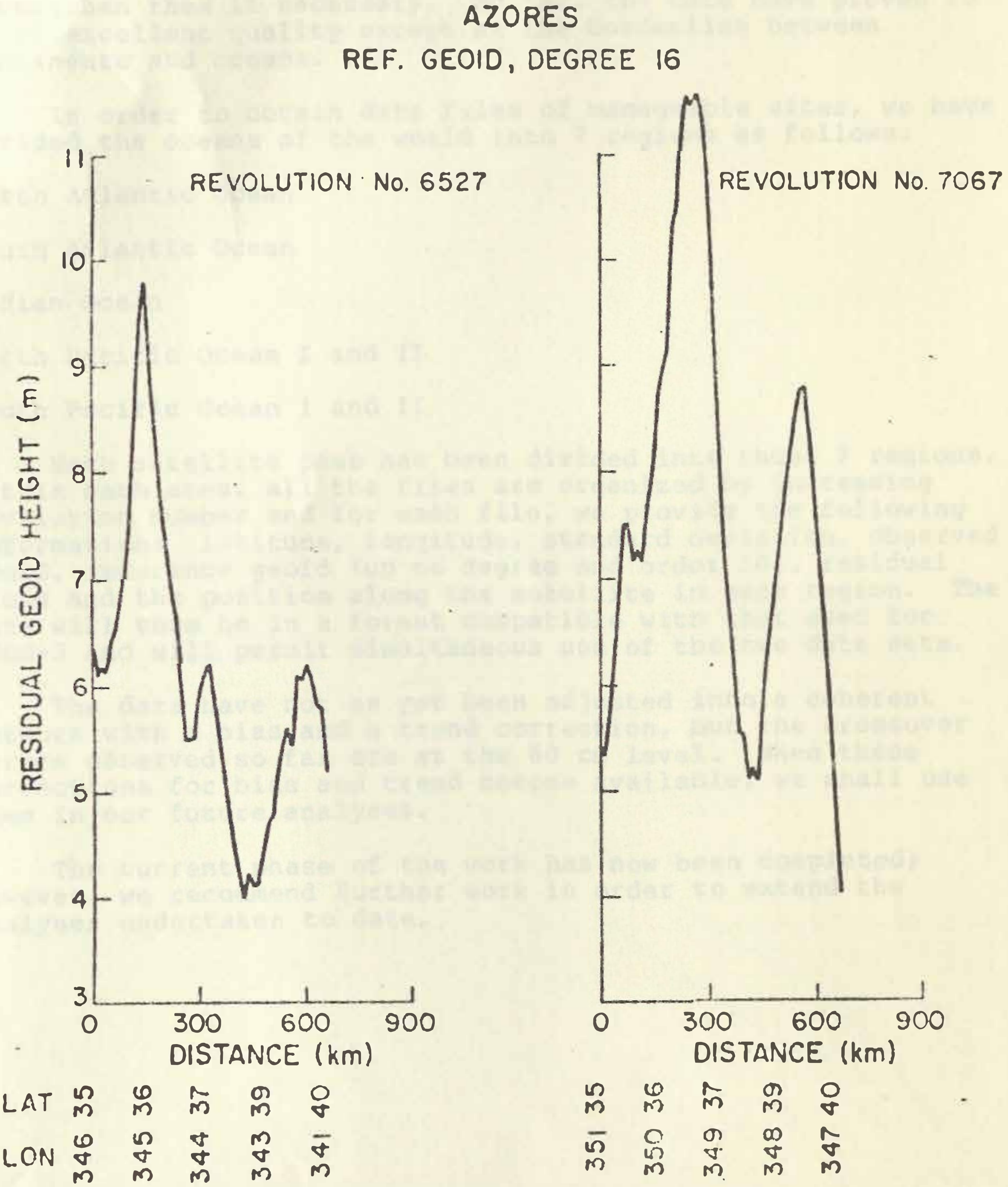
We have also studied the Rio Grande Rise in the South Atlantic Ocean. This area was chosen in order to be compared with the Walvis Ridge area studied previously, using the GEOS-3 data and located symmetrically with respect to the Mid-Atlantic Ridge. The geoid signals present in the Rio Grande Rise region are weak and broad and mostly resemble those observed in the eastern and central sections of the Walvis Ridge. At this point of the study, we believe that the Rio Grande Rise was formed simultaneously with the eastern and central sections of the Walvis Ridge by a migrating hot spot then located on the Mid-Atlantic Ridge. An Airy type model of compensation can best describe the signal observed. This study, because of the delay in the availability of the SEASAT data in the Southern Hemisphere, had to be completed with GEOS-3 data to provide good data coverage.

In the North Atlantic, we first contoured the intermediate wavelengths in the geoid height spectrum using the GEOS-3 data set, in collaboration with Dr. B. Parsons from MIT and Dr. D. McKenzie from the University of Cambridge, (U.K.). The very long wavelengths were removed by subtracting a reference geoid of degree and order 10 calculated with the GEM 7 spherical harmonic coefficients; the short wavelengths were removed by filtering along the tracks. In order to minimize cross-over errors, we used corrections for bias and trend provided by Dr. R. Rapp from Ohio State University. The geoid contours exhibit a 2 meter high along the mid-Atlantic Ridge, a 10 meter high over Bermuda and a 10 to 12 meter high over the Azores. We then retrieved and studied individual satellite passes over the Mid-Northern section of the Mid-Atlantic ridge. Typical crustal thickness calculated by the method described previously range between 8 and 15 km, in agreement with observations performed in that region. We further retrieved several GEOS-3 and SEASAT passes over the Azores. They all exhibit a short wavelength structure (figure 4) which reflects the succession of rises and abyssal plains present in that region.

Predictions are obtained in the Azores area using an Airy model and a thin elastic plate model. The results obtained so far tend to favor the Airy model with a crustal thickness of about 20 km. Further work is necessary, however, in order to gain more confidence in the validity of these preliminary results.

In April, 1981, we received 13 magnetic tapes containing the complete SEASAT Geophysical Data Set. Most of our effort since then has been directed towards reading and editing the tapes. Several criteria have been used to edit the data: all data points of geoid heights larger than +/- 150 m have been rejected as well as all geoid heights which differed by more

Figure 4
SEASAT and GEOS-3 Passes Over the Azores



than 15 m from the 3 preceding and 3 following points. Furthermore, several passes have been chosen at random and the observed and calculated geoids have been plotted (see Figures 5 and 6) to check the efficacy of the rejection criteria and strengthen them if necessary. So far, the data have proven to be of excellent quality except at the borderline between continents and oceans.

In order to obtain data files of manageable sites, we have divided the oceans of the world into 7 regions as follows:

North Atlantic Ocean

South Atlantic Ocean

Indian Ocean

North Pacific Ocean I and II

South Pacific Ocean I and II

Each satellite pass has been divided into these 7 regions. Within each area, all the files are organized by increasing revolution number and for each file, we provide the following information: latitude, longitude, standard deviation, observed geoid, reference geoid (up to degree and order 10), residual geoid and the position along the satellite in each region. The data will thus be in a format compatible with that used for GEOS-3 and will permit simultaneous use of the two data sets.

The data have not as yet been adjusted into a coherent network with a bias and a trend correction, but the crossover errors observed so far are at the 60 cm level. When these corrections for bias and trend become available, we shall use them in our future analyses.

The current phase of the work has now been completed; however, we recommend further work in order to extend the analyses undertaken to date.

Figure 5.

Observed and calculated geoid heights using SEASAT data, reduction number 954.

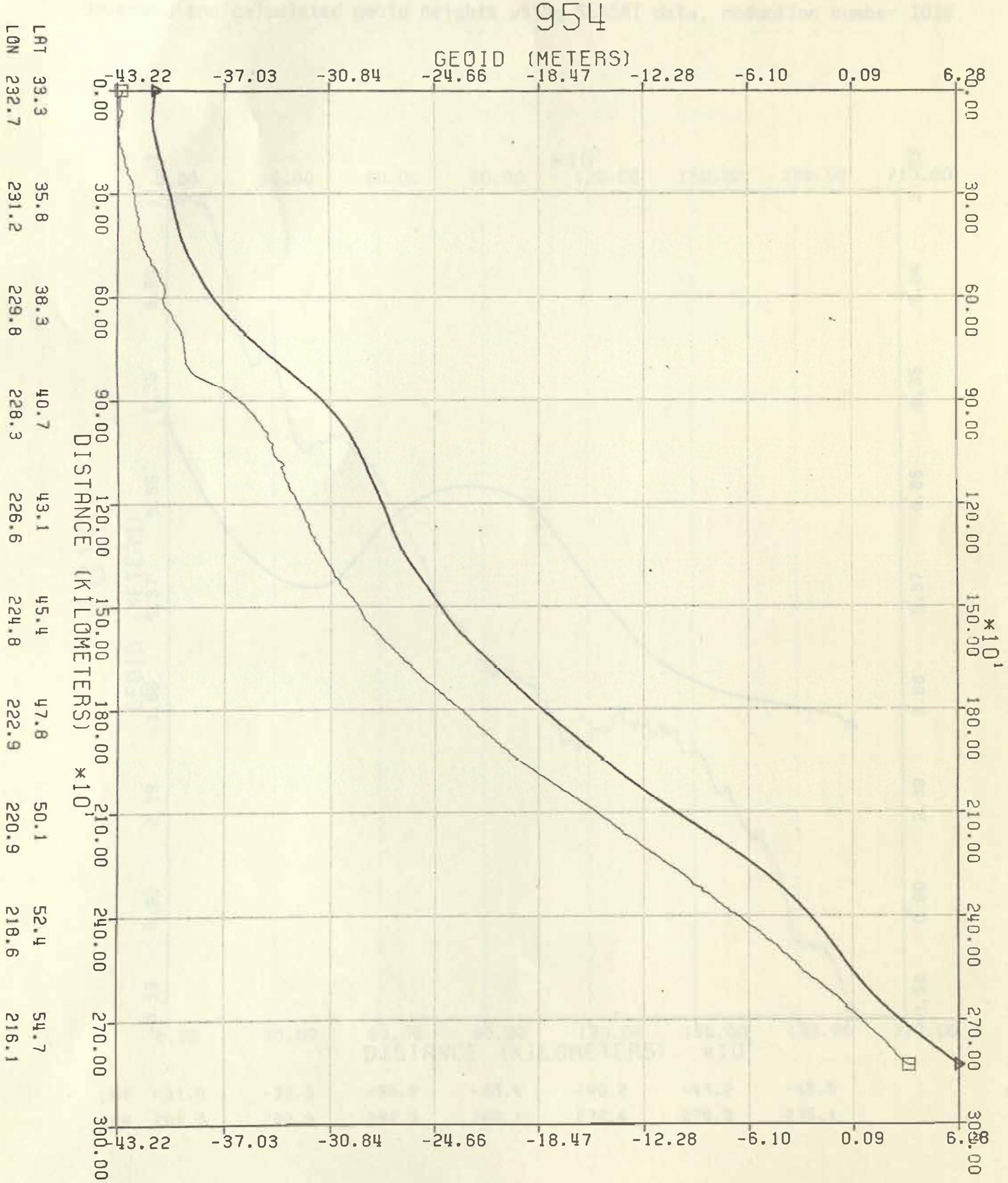
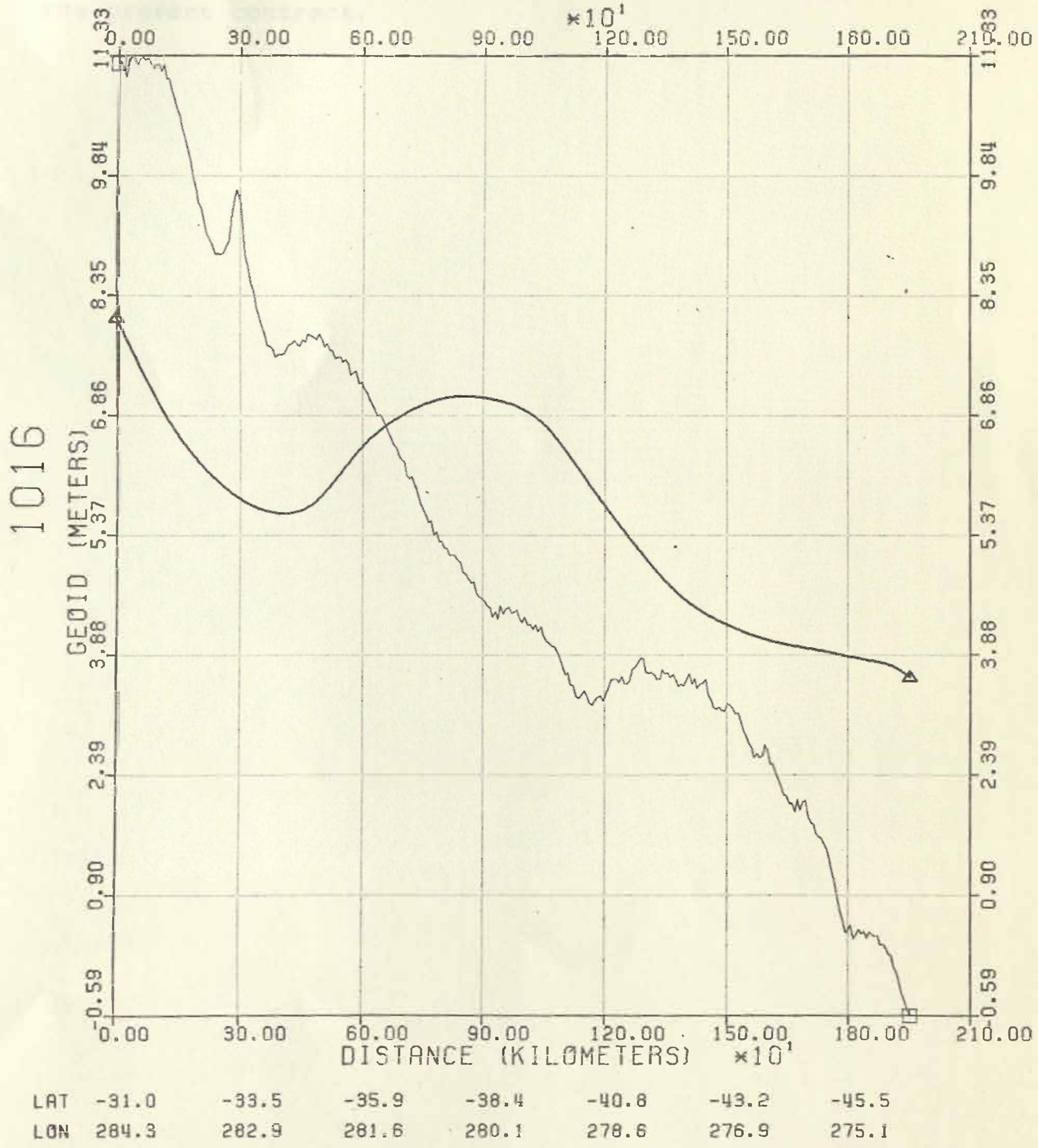


Figure 6.

Observed and calculated geoid heights using SEASAT data, reduction number 1016.



Estimated Funding Status

Of the total amount of $50,000, all funds have been expended, except for a small sum to support publication of the final report. Work on this project is complete under the present contract.