ORKUSTOFNUN
NATIONAL ENERGY AUTHORITY
GEOTHERMAL DIVISION

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Maps of Gravity, Bathymetry and Magnetics for Iceland and Surroundings

OS-95055/JHD-07
Reykjavík, December 1995

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ABSTRACT

In this report the National Energy Authority (Orkustofnun) presents a new compilation of gravity data in and around Iceland, comprising land data, shipborne gravity and satellite derived gravity. In our consideration the resulting map is more complete than other fairly recent gravity compilations, as far as the land and the immediate offshore area is concerned, where we include a great deal of good quality gravity data, especially at sea, some of which have not been published before. All publicly available marine (shipborne) gravity data collected in the time interval 1967 to 1985 have been screened in this study, but only those data sets which in our judgement are of sufficient quality and in significant quantity are included. In some cases the ship data are corrected with reference to the satellite data. Where shipborne data are too sparse or unsatisfactory only satellite gravity data are used, that are of good quality for wavelengths longer than 20 km but lack the short wavelength definition of the shipborne data. This is of relatively little consequence in deep-sea areas, but degrades the quality in areas such as the Reykjanes Ridge crest south of 63°N, the Greenland shelf and over the insular slope west of Iceland, where shipborne data are lacking.

On the basis of the compilation new maps have been produced in the scale 1:2,000,000 for the Bouguer and free-air gravity anomaly. They are plotted in Lambert Conic Conformal projection centered on Iceland and extending from approximately 32° to 6°W, and 60° to 70°N. As a by-product, a bathymetric/topographic map for the same area is produced, based on the digital terrain database constructed for the calculation of the Bouguer corrections. This relief model is based on digital elevation data from Iceland, underway ship soundings and the ETOPO5 database of world relief. The GEBCO Digital Atlas digitised bathymetric contour data are also evaluated by comparison.

In addition, we present a total field magnetic anomaly map of the same area, based on published gridded data from the aeromagnetic survey of Iceland, carried out by the Science Institute, University of Iceland, and the compilation published in the American "DNAG" series.

The full scale maps and the gridded data base are available on request from the NEA (Orkustofnun) for a modest price.

Acknowledgements

We thank the staff of the Science Institute, University of Iceland, for contributing data: Leó Kristjánsson and Geirfinnur Jónsson provided magnetic data sets, while Helgi Björnsson and Finnur Pálsson provided glacier thickness and surface elevation data. Gunnar Þorbergsson, NEA, provided access to gravity data and certain gravity processing programmes. The National Petroleum Directorate, Norway (NPD) kindly agreed to the use of data from the NPD/OS 1985 cruise in the Jan Mayen Ridge area. The GMT software by Wessel & Smith (1991,1995) was used for producing the maps and other data displays.

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1. INTRODUCTION

A programme of offshore resources reconnaissance has been active for some time at the Geothermal Division of the National Energy Authority (NEA; Orkustofnun), Iceland. During this work the need for a more comprehensive gravity compilation has been felt. There is also a distinct lack of digital bathymetric data for the insular shelf and slopes of Iceland, and existing magnetic field data are of varying formats. The present report has emerged from an effort to compile digital data bases of this type.

Although some fairly recent gravity compilations have been published, they have certain limitations. Þorbergsson et al. (1990) published a Bouguer gravity map of Iceland and the immediate offshore area. This map is based entirely on those data where NEA has been involved in the acquisition. While the general quality is good and the data density on land is satisfactory, the offshore data are limited in quantity and do not extend sufficiently far offshore. The more extensive international European gravity compilation project known as WEEGP (1994) has on the other hand the weakness of being incomplete on land and in near-shore areas, due to lack of local data.

I view of this it was felt justifiable to attempt a new gravity compilation, using both he internationally and locally available data sets. A great wealth of internationally pooled marine data is now easily available through electronic media, including new and comprehensive offshore gravity data derived from satellite measurements. The emphasis of the compilation work is on the insular shelf and slope of Iceland, where we attempt to combine the more detailed shipborne measurements with satellite measurements, which provide a more complete cover and better accuracy for the long wavelength of the field.

This work is a continuation of the long-standing traditional role of the NEA as the national surveying agency and depository for gravity measurements. A complementary bathymetric/topographic data base was now constructed for the purpose of calculating the gravity reductions. In order to complete the data base for potential field data and surface relief, gridded magnetics were acquired from other sources, Icelandic and international. It is expected that the data sets presented here will be valuable for offshore exploratory work and in general for large scale studies, but also for regional onshore exploration.

2. GRAVITY

2.1 Data sources

All marine (shipborne) gravity data used in this study are listed in Table 1, and Figure 1 shows the ship tracks and the data coverage.

An important part of the data set are marine data collected or stored by the National Energy Authority (NEA), in the immediate offshore area of Iceland, roughly corresponding to the area of the insular shelf. A comprehensive survey was carried out in 1972-1973 in cooperation with the US Defence Mapping Agency (DMA), and these data are described by Þorbergsson et al. (1990), and identified by the letters "sms" in Table 1. Additional gravity data in the possession of the NEA off the north coast of Iceland were acquired during seismic surveys by NEA in 1985 (carried out by GECO), and by Western Geopysical Co. in 1978.

A geophysical survey of the Jan Mayen Ridge area was carried out in 1985 in a joint effort by NEA and the National Petroleum Directorate, Norway (NPD). These data are included in the present compilation, but access is otherwise restricted.

Other ship gravity data used here are available as the "GEODAS" marine geophysical database on a compact disk from the National Geophysical Data Center (NGDC-NOAA), Boulder, Colorado, USA. This dataset is an international compilation of shipborne geophysical measurements made by academic and research institutions, and in this context the Boulder site is called World Data Center A. The notation for cruises in Table 1 is taken from this database. As is seen in Figure 1 the most important data of this class are the U.S. Navy data on the Iceland shelf, and the extensive surveys north, east and south of Iceland by the German Hydrographic Institute survey vessels (Metor 1968, 1970 and 1972; Komet 1971 and 1975. See e.g. Meyer et al., 1972; Fleisher et al. 1974). The German data are released through the International Gravity Bureau. The accuracy of these surveys has been improved in the present compilation by combined shipborne/satellite field processing (see below).

The above counted data sets provide a fair cover for the near-offshore areas all around Iceland, and a wide margin towards the north, east and partly in the south. Outside this area we use a new gravity field for the oceans derived from satellite altimetry data, which are made internationally available in digital form and fetched from Scripps Institution of Oceanography FTP Archive
(ftp://baltica.ucsd.edu/pub/global_grav_2min/ ; version 7.2, see e.g. Smith and Sandwell, 1995; Sandwell and Smith, 1996).
The cut-off wavelength of the satellite data is about 20 km, which is considerably worse than the high quality shipborne data, which have a resolution down to 6 km wavelength.

Table 1. Marine gravity and bathymetric data.

Data source and survey	Time of survey	Number of gravity points	Number of bathymetric points	Survey length (km)	Average point interval (km)
NEA (National Energy Authority, Iceland):					
sms05	20-23/6/1972	267	225	1140	4.29
sms06	30/6-11/7/1972	640	621	2503	3.92
sms07	16-18/7/1972	190	190	689	3.65
sms09	29-30/7/1972	182	182	590	3.26
sms08	3-10/8/1972	501	501	1653	3.31
sms04	18/5-10/6/1973	700	687	2567	3.67
sms03	19-24/6/1973	590	381	1853	3.15
sms02	27/6-10/7/1973	583	510	1929	3.30
sms10	18-24/7/1973	681	679	2146	3.16
sms11a	2/8/1973	20	20	47	2.45
sms11b	2-3/8/1973	23	23	69	3.15
sms11c	8-12/8/1973	491	492	1486	3.02
sms11d	21-24/8/1973	289	289	917	3.19
sms12	25-30/8/1973	673	673	2003	2.98
sms13	6-15/9/1973	492	490	1709	3.48
sms14	15-17/9/1973	159	159	500	3.16
NPD/NEA (Jan Mayen Ridge data):					
J/NH-79	22-29/7/1979	2241	2241	1112	0.50
JM-85	21/7-31/8/1985	13503	14303	4210	0.31
GECO/NEA:					
F-85	13-17/8/1985	1176	1176	578	0.49
W.G.Co./NEA:					
ISPEC-78	10-28/11/1978	5096	5169	854	0.17
GEODAS, US Navy:					
dut07_68	11/7/1967	158	0	86	0.55
kea01_70	25/7-3/8/1969	5795	0	2163	0.37
bow03_70	17/9-2/10/1969	460	0	366	0.80
bow07_70	27-31/3/1970	185	0	136	0.74
dut09_70	28/3-14/4/1970	2000	0	1736	0.87
dut02_70	6-12/6/1970	3680	0	2234	0.61
kea01_71	1-8/8/1970	5893	0	2069	0.35
dut03_71	11-25/8/1970	8040	0	5139	0.64
kea03_71	16/10/1970	112	0	36	0.32
kea10_71	29/5-18/6/1971	6299	0	2457	0.39
kea11_71	23/6-17/7/1971	1710	0	853	0.50
kea01_72	25-26/7/1971	1847	0	567	0.31
ba75e	28/8-3/9/1975	1363	15251	1813	0.07
GEODAS, International Gravity Bureau:					
me14a	5-19/7/1968	1549	1549	5508	3.56
me14b	26/7-4/8/1968	1063	1060	3651	3.44
me14c	7/6/1970	113	113	366	3.27
me20a	7/7/1968	70	70	235	3.41
me20b	19-24/7/1968	576	574	1867	3.25
me20c	31/5-4/7/1970	3530	3569	13140	3.67
kt1a	19/8-3/9/1971	1540	1451	7170	4.43
kt1d	8-15/9/1971	753	755	4201	5.52
kt1b	4-24/9/1975	2546	2552	8520	3.33
kt1c	29/9-3/10/1975	424	422	1254	2.96
me28a	16-29/9/1972	1570	1586	6336	3.97
me28b	2-19/10/1972	2039	2018	5640	2.77
GEODAS, UK data:					
STA179A	25-28/9/1979	2168	2046	986	0.45

While a great deal of other shipborne gravity data from our area are found in the GEODAS data set, mostly in the form of irregularly distributed tracks and of varying quality. We feel that due to the aliasing effects and inconsistencies, these data would not enhance the quality of our map in areas where the regularly spaced shipborne data do exist. This is especially true for the shallow Iceland shelf. In the areas where we have chosen to use only the satellite data, the sparsity of shipborne data is in general too great for the areal mapping of the short wavelength component of the field, while the longer wavelengths are apparently better represented by the satellite data.

The land gravity data from Iceland used here were all collected by the NEA, mostly in cooperation with the DMA of USA. They were previously published by Þorbergsson et al. (1990) and are listed in Table 2. We use all data collected for regional studies, and for which terrain corrections exist. They provide a fairly complete and even coverage for the whole country. A great deal of other data do exist, from local surveys and sources other than the NEA, which are not included, except some data on the north coast in the vicinity of Flatey and Húsavík (Karl Gunnarsson, 1985).

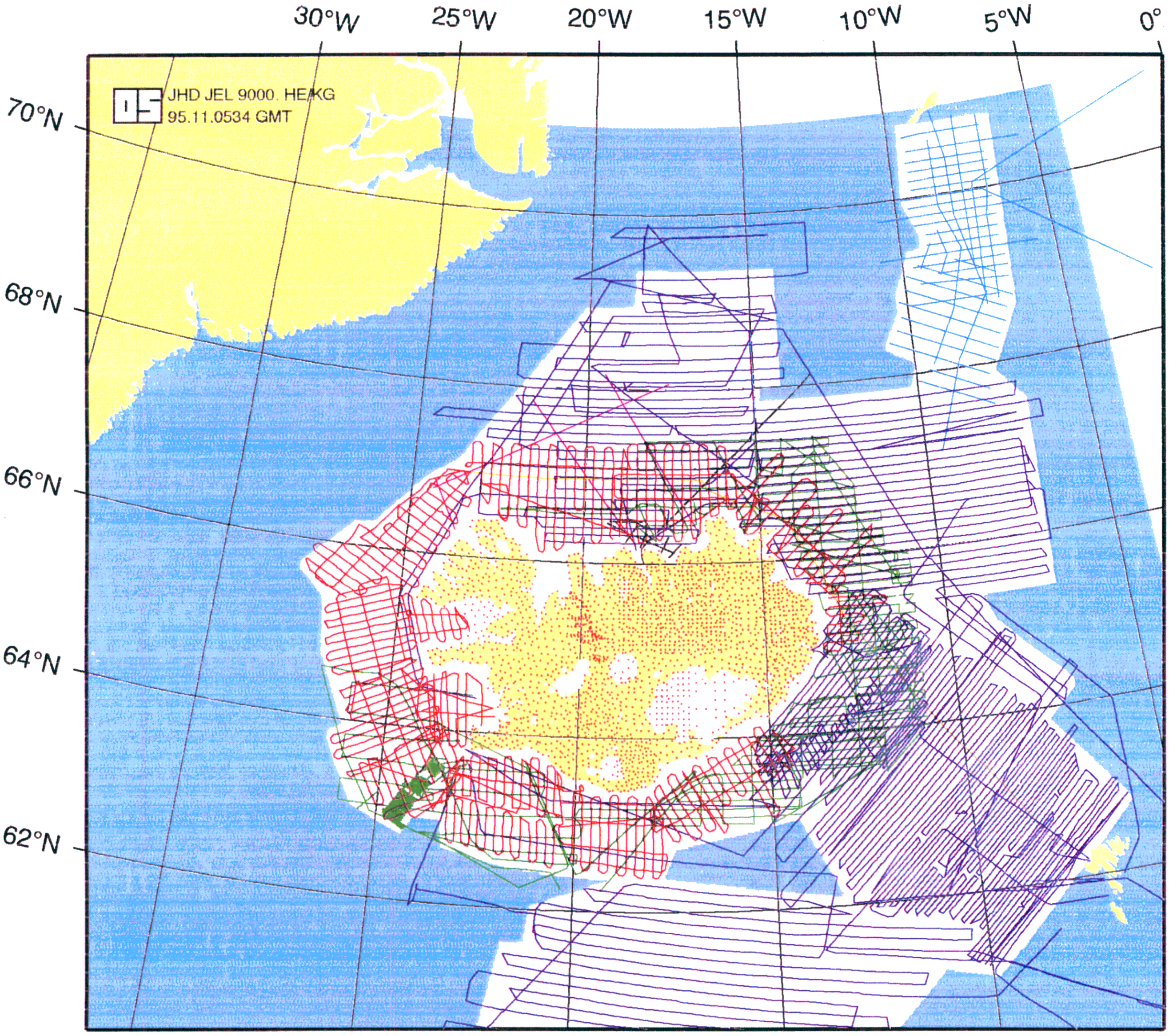
The various types and origins of the primary data must be kept in mind while using the resulting gravity map. This will be especially noticeable in the lower frequency content of the satellite data, but as the shipborne data cover most of the very shallow areas where the short wavelength is most pronounced, this effect is not very serious. It should be noted that while the data here presented for the Iceland shelf can be considered the best available, better local data would probably exist for other areas, such as the Greenland shelf. We use no ship data over the Reykjanes Ridge south of 63°N, as the quality of available data appears questionable. The ridge is presently under study in the context of the "InterRidge" programmes, and it can be expected that better quality data will soon emerge from this activity and be made available. (A new gravity map of this area has recently been published by Hwang and Parson (1995) based on satellite and older shipborne gravity, but the better quality data on the Iceland shelf are not included).

Table 2. Land gravity data.

Data file	Time of survey	Number of points	Inner Bouguer radius (km)	Outer Bouguer radius (km)	Note
gravland.v85	1967-1971	1564	9.903	167	1)
parta.v85, partc.v85	1985	582	6.653	167	1)
-"-, only glacier stations	1985	103	2.612	167	1)
flatey81	1981	53	6.653	167	2)

1) Þorbergson et al. 1990

2) Karl Gunnarsson 1985; pers. comm. 1995.



The sources of gravity data are indicated by colour as follows:

GECO/NEA	W.G.Co.	NPD/NEA	Int. Grav. Bur.	
UK	US Navy	NEA–land	NEA	Satellite

Figure 1. Data coverage for the gravity database used in the making of the map on Figs. 4 and 5 and Plates 1 and 2. Ship tracks and satellite cover at sea and gravity stations in Iceland (see Tables 1 and 2).

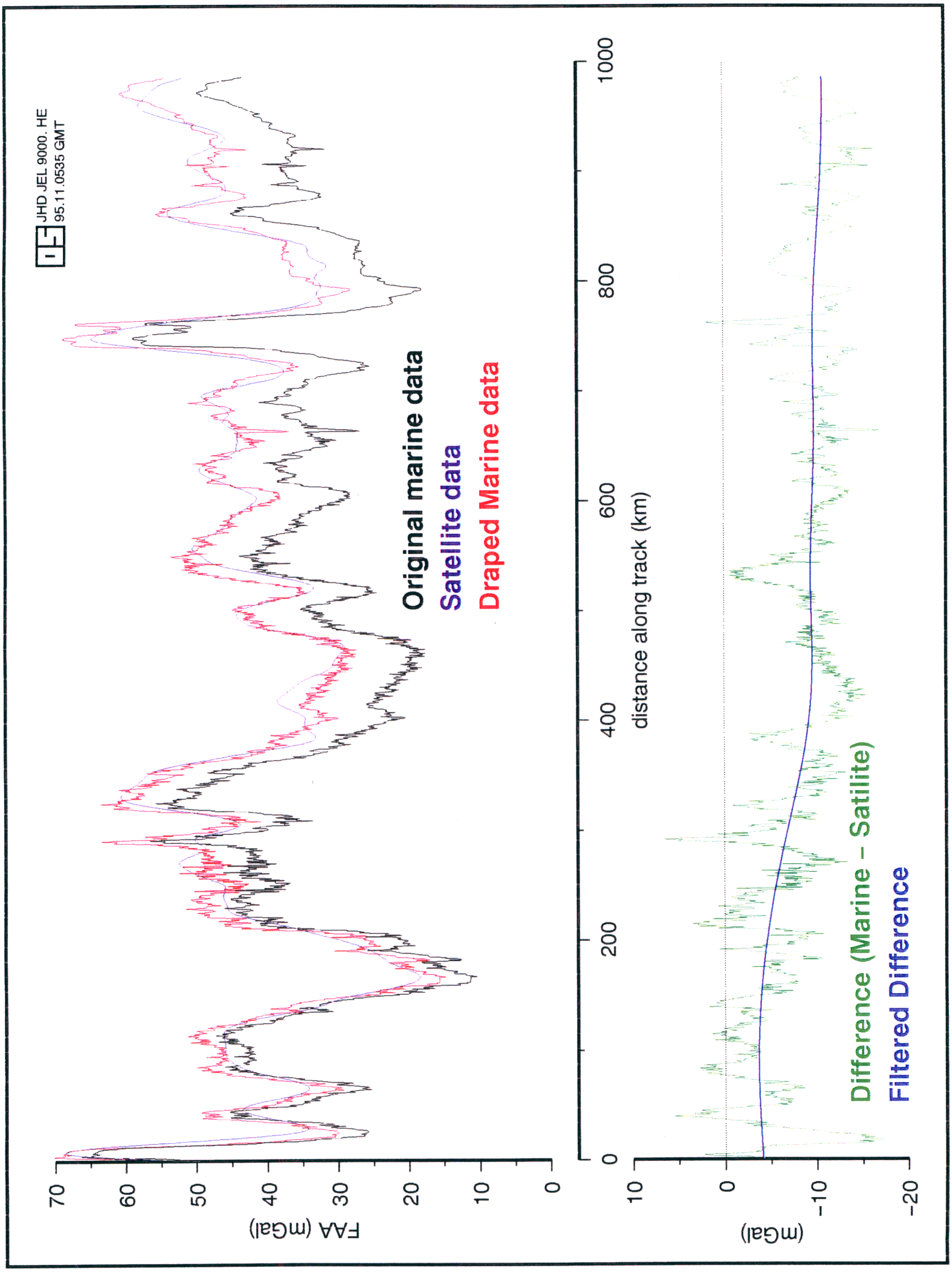


Figure 2. A sample profile from a survey, showing the effect of correcting the long wavlength "drift" of the shipborne data by reference to the interpolated satellite gravity data along the ship track.

2.2 Primary data processing

The gravity data have been adjusted to the IGSN71 (International Gravity Standardisation Network) reference system. Data with recorded reference station in Iceland are adjusted to IGSN71/V85, which is a refined reference, made with ties between USA-Iceland-Norway in 1985 (Þorbergsson et al. 1990, p.9). This reference is 0.9 mGal lower than the previous definition. We feel that any possible inconsistencies in the reference for various cruises, having made gravity ties in Iceland, would cause insignificant errors after the data processing applied. The normal gravity formula used is GRS80 (Geodetic Reference System 1980, Moritz 1984).

In all the marine gravity surveys used here, the Eotvos corrections have been applied as calculated by each surveyor. The marine gravity data were carefully examined in order to eliminate spikes and other obvious errors.

The cross-over errors for the ship tracks of the raw data compilation were found to be quite large, often tens of mGal and even up to 100 mGal. Furthermore there are some discrepancies between the shipborne gravity data and the satellite gravity. Figure 2 shows a sample of a continuous profile from a survey, comparing the shipborne data and the interpolated satellite gravity data along the ship's track. As expected the shipborne gravity shows more details (shorter wavelengths) than the satellite data. However, there is also some discrepancy in the longer wavelengths, most likely due to instrument drift and other errors in the shipborne data, as the satellite date are considered more accurate for longer wavelengths. The following data processing procedure was employed, designed to combine the resolution of the shipborne data with the accuracy of the longer wavelengths of the satellite data (adopted from the "WEEGS" report).

1. For each ship survey point we calculate the satellite gravity value by interpolation (blue curve in Fig. 2), and subtract from the ship gravity value to find the difference, shown as a green curve in Fig. 2, where the curves are presented as a function of distance along track.
2. We then filter out from the difference curve all wavelengths shorter than 500 km, obtaining the long wavelength error function for the marine data (light blue curve), which we assume to be a reasonable approximation of the long term instrumental drift and DC errors in the data.
3. This "error function" is then subtracted from the original ship gravity function to get "draped shipborne gravity data" (red curve).

This method ensures good compatibility between marine and satellite data, while preserving the high resolution information of the marine data. It also gives an improved agreement between different marine surveys, better than using only DC correction for individual surveys based on mis-tie analysis.

In the final version of the compilation, this procedure was actually only applied to the German Inst. Hydrology cruises, while the other ship data on the Iceland insular shelf are of better quality and show no significant improvement by this treatment.

After applying this "drapering filter" to the marine data the overall crossover mis-ties decrease dramatically. Figure 3 shows a histogram of the mis-ties for all crossings of the ship tracks used in the compilation. After the satellite corrections the standard deviation of the mis-ties of the chosen shipborne data set is found to be 2.7 mGal, which is considered satisfactory. The largest remaining values (> 10 mGal) occur at locations where the gravity gradient is steep, suggesting that positional errors and possibly limited instrument response are the largest remaining sources of error. Before gridding the data using minimum curvature splines with tension (Wessel and Smith, 1995), the data were averaged within 2 by 1 arc-minute blocks (1.6 by 1.85 km in the center of the map).

The resulting gravity maps are based on 2200 land gravity points, 84000 shipborne points, and 49000 satellite points, a total of about 135000 points. All the maps are drawn in a Lambert conic conformal projection, with center at 65°N and 18°W, and the two standard parallels both at 65° N. This is a standard national projection for Iceland. The gridding interval is 2 by 2 km at the center of the map.

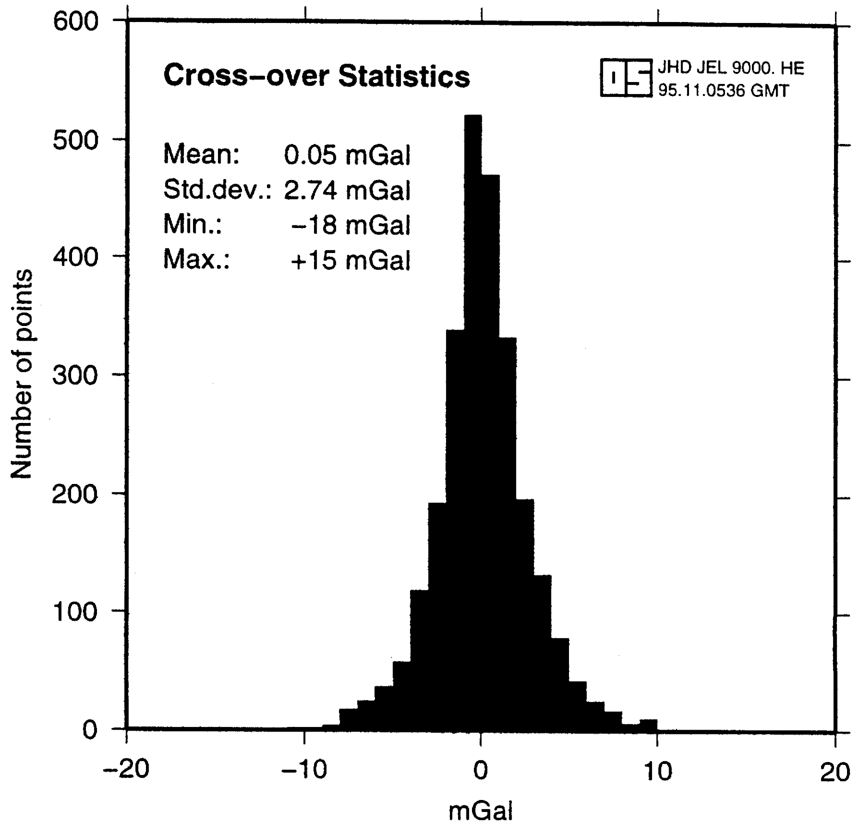


Figure 3. A histogram for the mis-ties of all cross-over points for the shipborne gravity measurements after final processing. The standard deviation of the mis-ties is 2.7 mGal.

2.3 Free-air gravity anomaly

As the position of a gravity survey point affects the measured gravity value, it is necessary to "correct" the observed readings in order to obtain comparable values between different station locations on the earth surface. Gravity data are thus generally displayed either in terms of so-called free-air anomaly or Bouguer anomaly.

In the free-air correction the observed gravity is corrected due to the elliptical shape of the earth, i.e. due to latitude location, as well as due to elevation of the survey point. The free-air gravity anomaly is calculated according to the formula:

$$g_{free} = g_{obs} - g_{norm} - 3.0855 \cdot h \tag{1}$$

where g_{obs} is observed gravity (IGSN71 reference) and g_{norm} is the normal gravity formula (GRS80) expressed according to Torge 1989 as:

$$g_{norm} = \gamma_0 \frac{1 + k\sin^2\theta}{\sqrt{1 - e^2\sin^2\theta}} \tag{2}$$

with:

$$\gamma_0 = 978032.67715 \text{ mGal}$$
$$k = 0.001931851353$$
$$e^2 = 0.0066943800229$$

θ being the geodetic latitude and h the elevation of the survey point. No correction is applied due to the mass of the atmosphere. Since topography affects the land gravity data dramatically in terrain areas like Iceland, it is not feasible to display the free-air anomaly for data on land. Therefore on the the free-air anomaly map (Plate 2) Bouguer anomaly (see below) is displayed for the land data, and since all the marine data are measured at sea-level (h is taken as zero) the only correction for the free-air anomaly over the marine area is due to the elliptical shape of the earth. This free-air anomaly map is also shown in a simplified version on Figure 4.

2.4 Bouguer gravity anomaly

In addition to the free-air correction it is also necessary to correct for the gravity effects of the topographic masses below and around the survey station. The reference surface is sea-level. The goal of Bouguer correction is to estimate the reading that would have been measured if there where no deviation of the terrain from the reference level, i.e. no hills and the sea-water layer replaced with land masses. Thus, the Bouguer anomaly is expected to reflect only the density changes below the earth's surface.

On Plate 1 we present a coloured contour map of the Bouguer gravity anomaly, which is also shown simplified in Figure 5. The Bouguer anomaly has been calculated for all data point at sea and on land, using a uniform density of 2600 kg/m^3. The procedure employed here for the Bouguer correction is rather complex. Outside a certain radius, the "Inner Bouguer Radius", a digital model is used to calculate automatically the total effects of topography out to 167 km radius, modelled as blocks extending above or below sea-level. The curvature of the earth's surface is taken into account. Inside the "Inner Bouguer Radius" we use the traditional method of subtracting the effects of a slab below the station height, followed by terrain corrections manually estimated by the use of a Hammer template. However, the slab is truncated at the Inner Bouguer Radius, forming a cylinder.

The Bouguer gravity anomaly is then calculated according to:

$$g_{boug} = g_{free} + c_{bp} + c_{bt} + c_{bo} \qquad (4)$$

where g_{free} is the free-air gravity anomaly, followed by the three correction terms.

The first correction term, c_{bp}, is the so called truncated Bouguer plate correction. This term is negative for land stations and corrects for effect of the masses between the reference height (sea level) and the observation height, but positive for offshore data as it replaces seawater with heavier crustal material. This is done by calculating the gravity effect of a cylinder with the center at the observation point according to:

$$c_{bp} = 2\pi G\rho h\,(R + h - \sqrt{R^2 + h^2}\,) \qquad (3)$$

where G is the gravitational constant, h is the elevation of the survey point, R is the inner Bouguer radius, and ρ is 2.6 g/cm^3 and 1.57 g/cm^3 (2.6-1.027) for land and marine data respectively. For the land data R is either 6.65 or 9.9 km, except for stations located on glaciers (see table 2), and for marine data R is 2.615 km.

A slightly different procedure is used for gravity stations located on glaciers, since the density of the ice (0.9 g/cm^3) differs from the rock. Elevation and thickness data for three of the four largest glacers (Vatnajökull, Hofsjökull and Mýrdalsjökull) was kindly provided by the Science Institute, University of Iceland (Helgi Björnsson 1988; pers. comm. 1995). The thickness of other glacers has not yet been measured. The truncated Bouguer plate correction term for those data points is calculated in two steps. First using equation 3 with density of 0.9 g/cm^3 and h as the thickness of the ice sheet, and secondly using a similar formula for a cylinder starting at depth h down to sea level, with density 2.6 g/cm^3. For the glacier data R is chosen as 2.615 km.

The terrain corrections (c_{bt}, always positive) for the land data were done in the traditional way (Hammer, 1939) out to zones J or K, radius of 6.65 or 9.90 km respectively, which correspond to the Inner Bouguer Radius (see Table 2). This correction is due to elevation variation from a horizontal plane at the elevation of the gravity station. This term had already been estimated for the land data by Þorbergson et al. (1990), and Gunnarsson (1985, partial publication), except for stations located on glaciers. For those relatively flat glacier locations we assume that this correction term is zero out to zone H (radius 2.6 km). The same applies to the marine data, as we assume that the sea-floor is sufficiently close to being flat beneath each survey point out to 2.6 km.

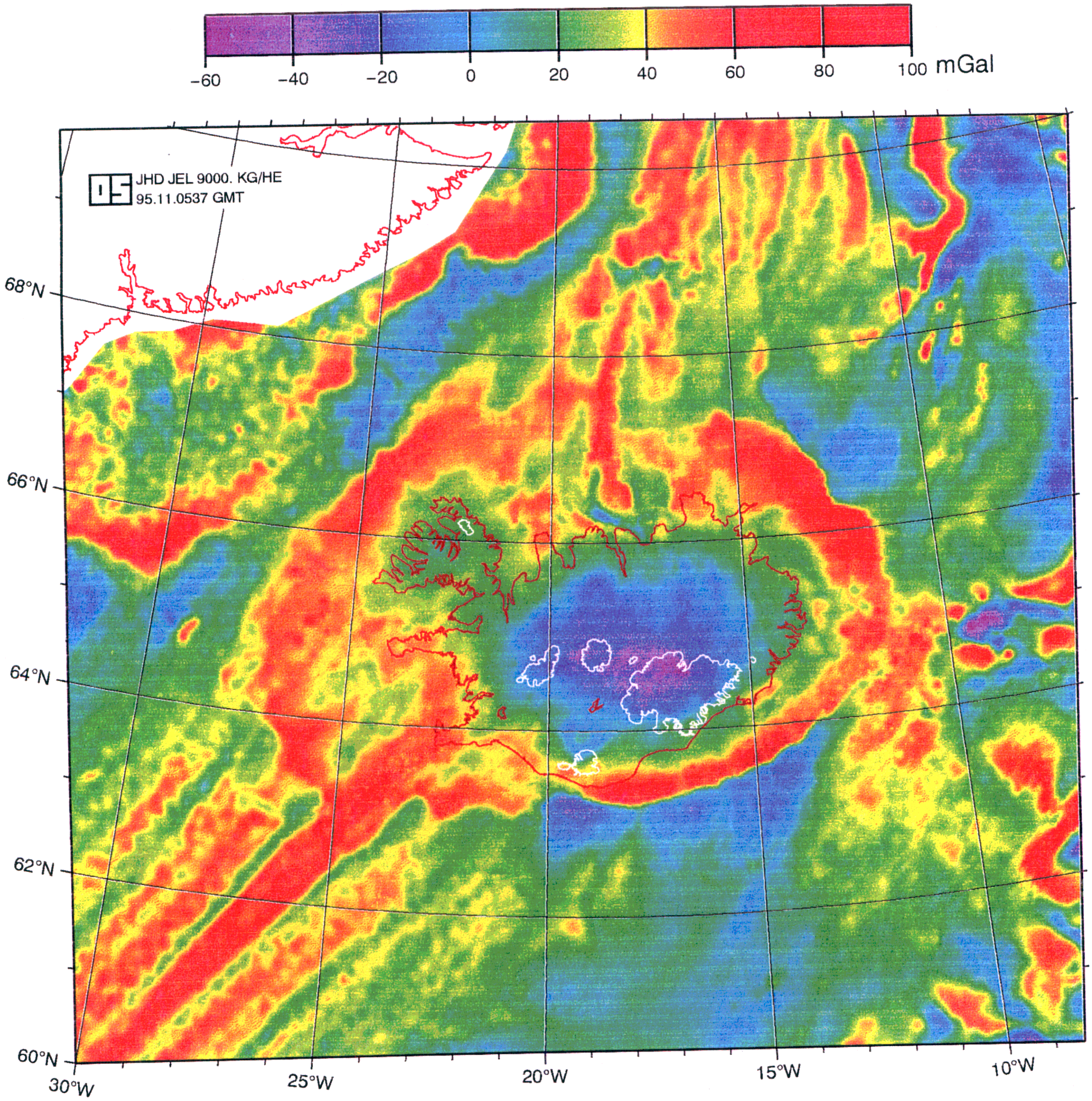


Figure 4. Free-air Anomaly map. On land in Iceland the Bouguer Anomaly is used.

The third correction term (c_{bo}) accounts for the effects of topography/bathymetry outside the Inner Bouguer Radius, out to 167 km (Outer Bouguer Radius) from the survey point. The program TOCORR (Þorbergsson, pers. comm.) calculates the effect of masses above see level for the land data and the effect of interchanging seawater with crustal masses for the marine data. The bathymetric gridded model OSHAF95-Topography (a 2' by 1' grid, see below) is used for these calculations.

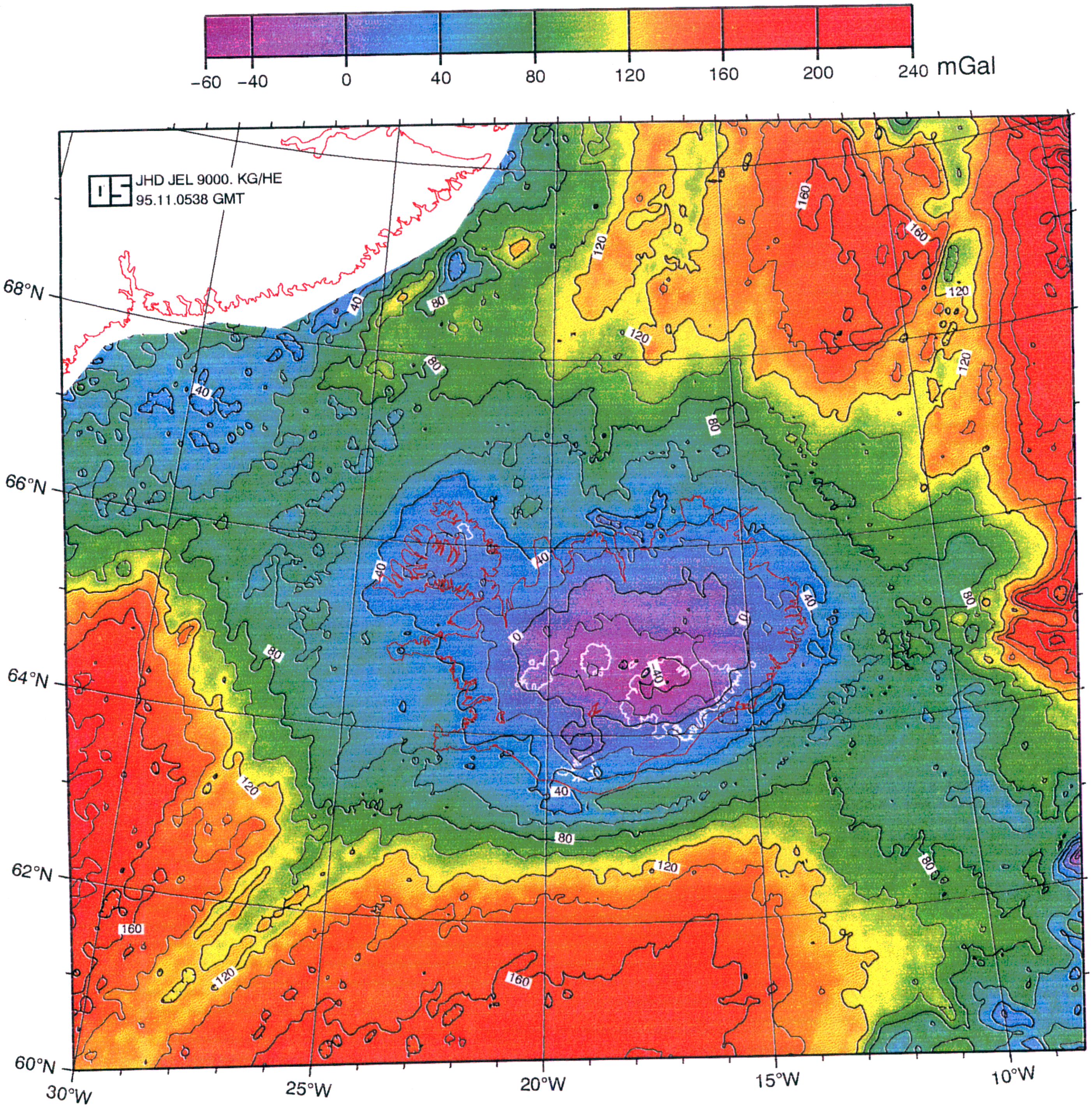


Figure 5. Bouguer Anomaly map.

The program TOCORR calculates the gravity effect of a square block for each grid point (or part of a block if the Inner Bouguer Radius intersects the block), and the effect of the earth's curvature is taken into account.

Because of the sizable glaciers in Iceland it is actually necessary to calculate this term in two steps for blocks containing the ice layer, first by using the elevation of the surface of the glaciers and density 0.9 g/cm^3, and secondly using the bottom elevation of the ice with density 1.7 g/cm^3 (2.6-0.9=1.7). Those two terms added together give the correct results for the two layered rock-ice model.

3. BATHYMETRY

3.1 Relief model for gravity reductions

A topographic/bathymetric model has been constructed for topographic corrections of the gravity data, here referred to as OSHAF95-Topography. This model is used for the corrections outside the "Inner Bouguer radius". For the 1990 publication of the Bouguer map of Iceland a digital topographical model was constructed (Gunnar Þorbergsson et al., 1990; file "REITIR", pers. comm.). This model consists of a grid of mean elevations of cell size 2' of longitude by 1' of latitude (corresponding to approx 1.56 km east-west and 1.85 km north-south). The new model, OSHAF95, has the same grid cell dimensions and includes part of a previous model as one source of data, but is more extensive and presumably better as it is compiled from miscellaneous elevation and sea-depth digital sources available to us. The elevation of the Iceland land area is based on:

1. The existing Þorbergsson (1990) model ("REITIR").
2. Elevations for surface and bottom of glaciers (Helgi Björnsson, pers. comm.)
3. Elevation of gravity stations Þorbergsson et al. 1990),
4. Digitised contours at 100, 200, 300, 600, 900 and 1500 m elevations (NEA).

The topography of the bottom of the glaciers is not presented here and is, of course, not included in the topographic map and only used for the gravity processing calcualtions.

Figure 6 shows the offshore data coverage used for the bathymetric model. Most of the marine gravity surveys used here include bathymetric measurements (see Table 1), which we used for the near field correction for the gravity data, and included in the relief model. In deap-sea areas, where those survey data do not cover the map area, bathymetric data from the ETOPO5 world wide database (5-minute grid) were used (NGDC, Global Relief Data, DC-ROM). The REITIR gridded data are also used in bays and strips of sea areas along the shores of Iceland, where ship tracks are lacking.

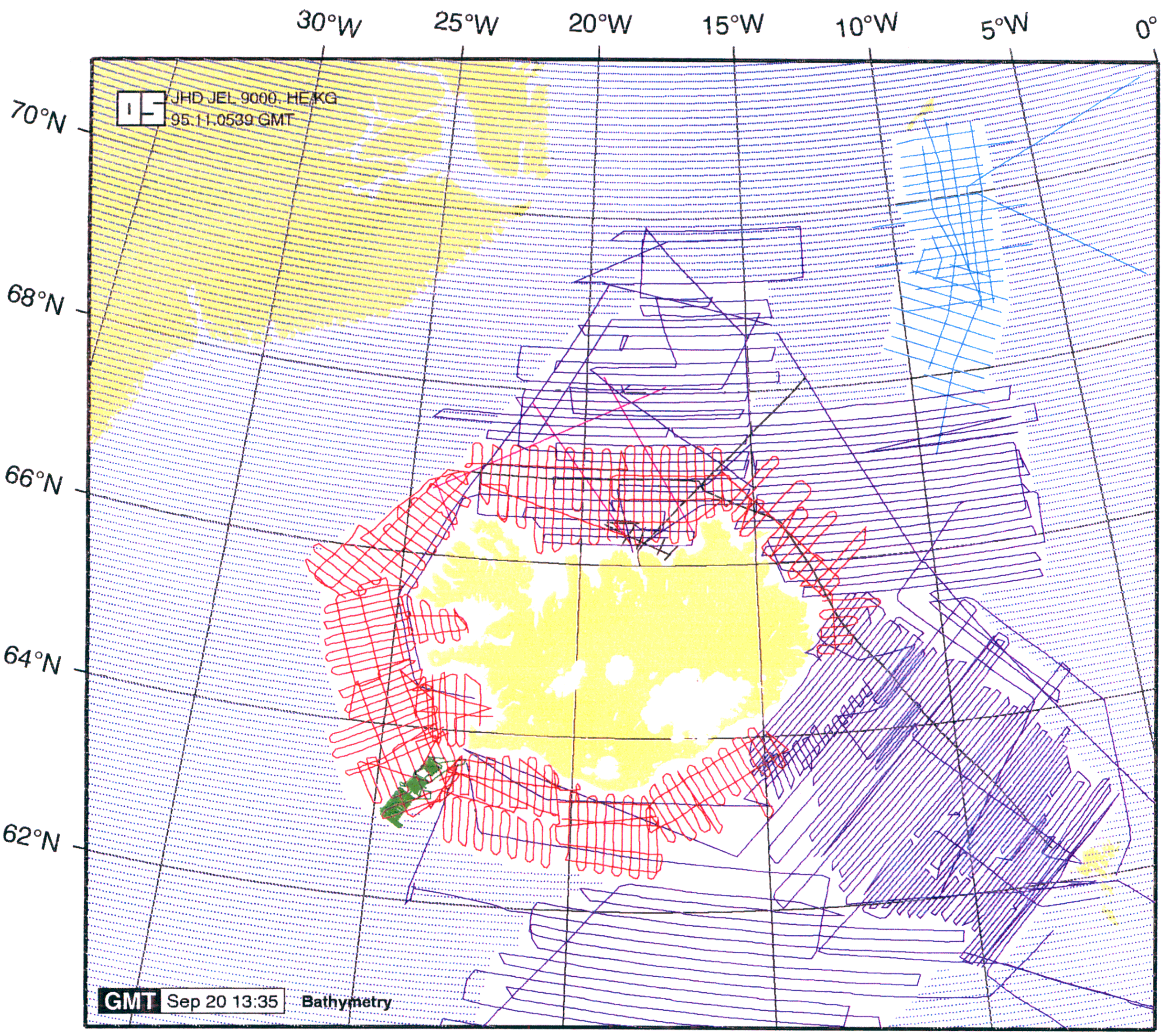
The resulting compiled data set is presented in the form of a contour map in Plate 3, and in a simpler version in Figure 7, with contours at 50 m intervals. The basic data are the same as for the Bouguer correction model, but a special grid is prepared for the map, which is an equidistance 2 km grid in the Lambert conical projection used here.

3.2 GEBCO Bathymetry

For comparison, we investigated an alternative digital data base, the international General Bathymetric Chart of the Oceans (GEBCO) Digital Atlas, which is distributed on DC-ROM and includes all of the world's oceans (IOC, IHO and BODC, 1994). These data are not gridded, but presented as a set of digital vectorised bathymetric contour lines, digitised from the corresponding published hand-contoured charts. In the Iceland area the contours are at 100 m intervals, and are shown in Figure 8. This area is found on the original GEBCO sheet 5.04 (published in printed form at 1:10,000,000, compiled by A.S. Laughton and D. Monahan).

The GEBCO Digital Atlas includes the survey track coverage (not drawn here), which in general corresponds to the GEODAS marine digital data, which are also the basis of the present model (partly through inclusion in the ETOPO5 database). Judging from the track coverage, the GEBCO map must in places also be constructed with reference to detailed local maps, such as for the Iceland shelf. A comparison between some selected GEBCO contours and corresponding contours from the OSHAF95 model is shown in Figure 9. The GEBCO contours indicate more details, as can be expected from the manual contouring method, but it must be realised that the details are often based on interpolation and interpretation of the topography, and thus not totally reliable. The OSHAF95 model is partly based on smoothed data (ETOPO5; up to 10 km grid interval), and the final gridded data are also affected by some smoothing or filtering (blocking of about 2 km dimension).

In some places the contours of the two models are practically coincident, while in other places considerable and consistent shifts are seen, often of the order of 10 kilometers, e.g. on the continental (insular) slope south and west of Iceland. A visual comparison with maps of the Iceland Hydrographic Office shows in many instances, especially close to Iceland, a better correspondence with the present OSHAF95 contours than the GEBCO contours. This indicates that our model could be partly better, in spite of less details. In general, it may be deduced that bathymetric mapping around Iceland is far from being complete or up to exacting modern standards.



The bathymetry data sources are indicated by colour as follows:

GECO/NEA W.G.Co. NPD/NEA Int. Grav. Bur.
UK US Navy NEA ETOPO5

Figure 6. The marine data coverage for the bathymetric map of Fig. 7 and Plate 2. The same base is used for the model for the correction of the gravity data for the effect of topography.

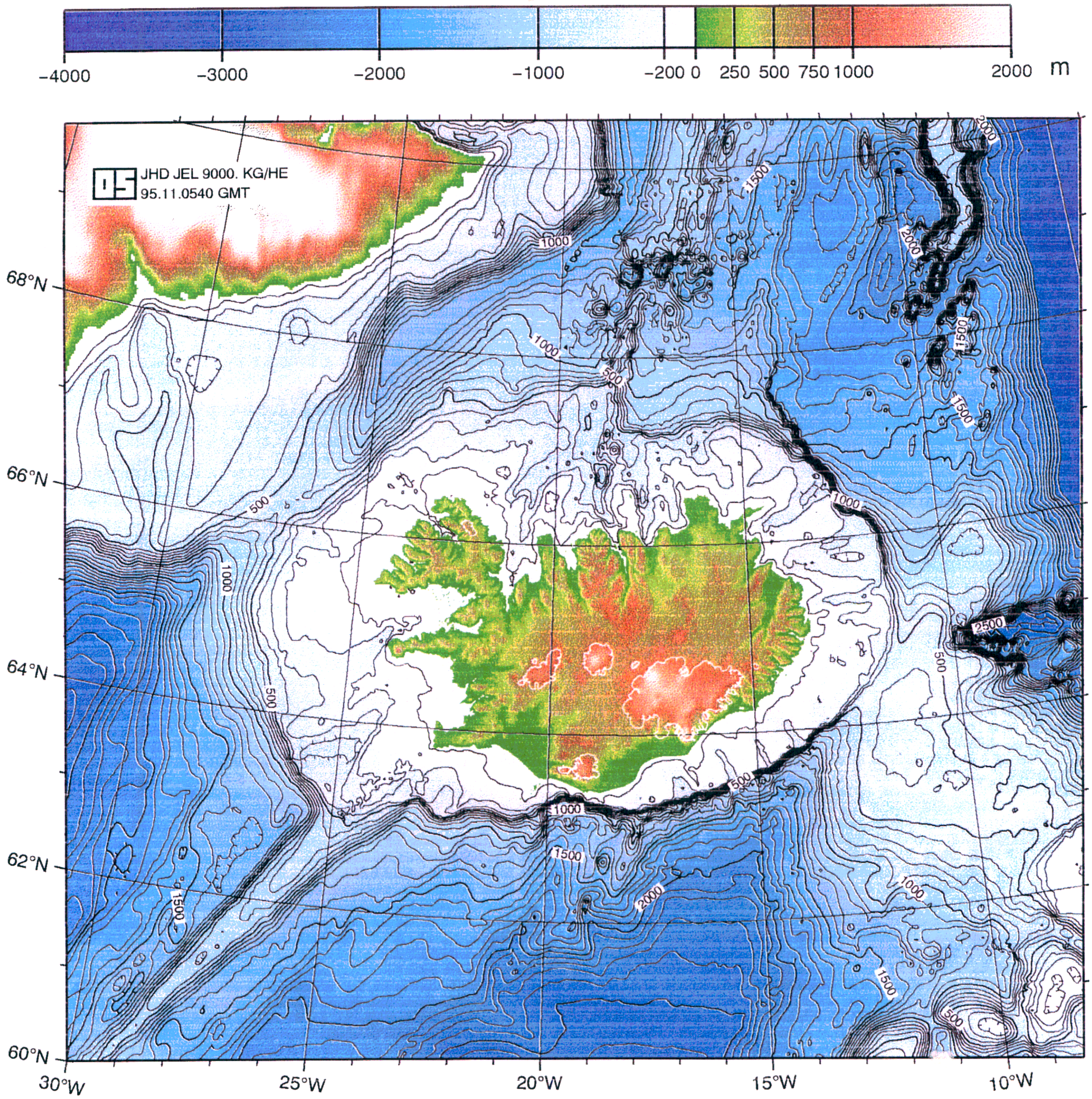


Figure 7. Bathymetry/Topography map.

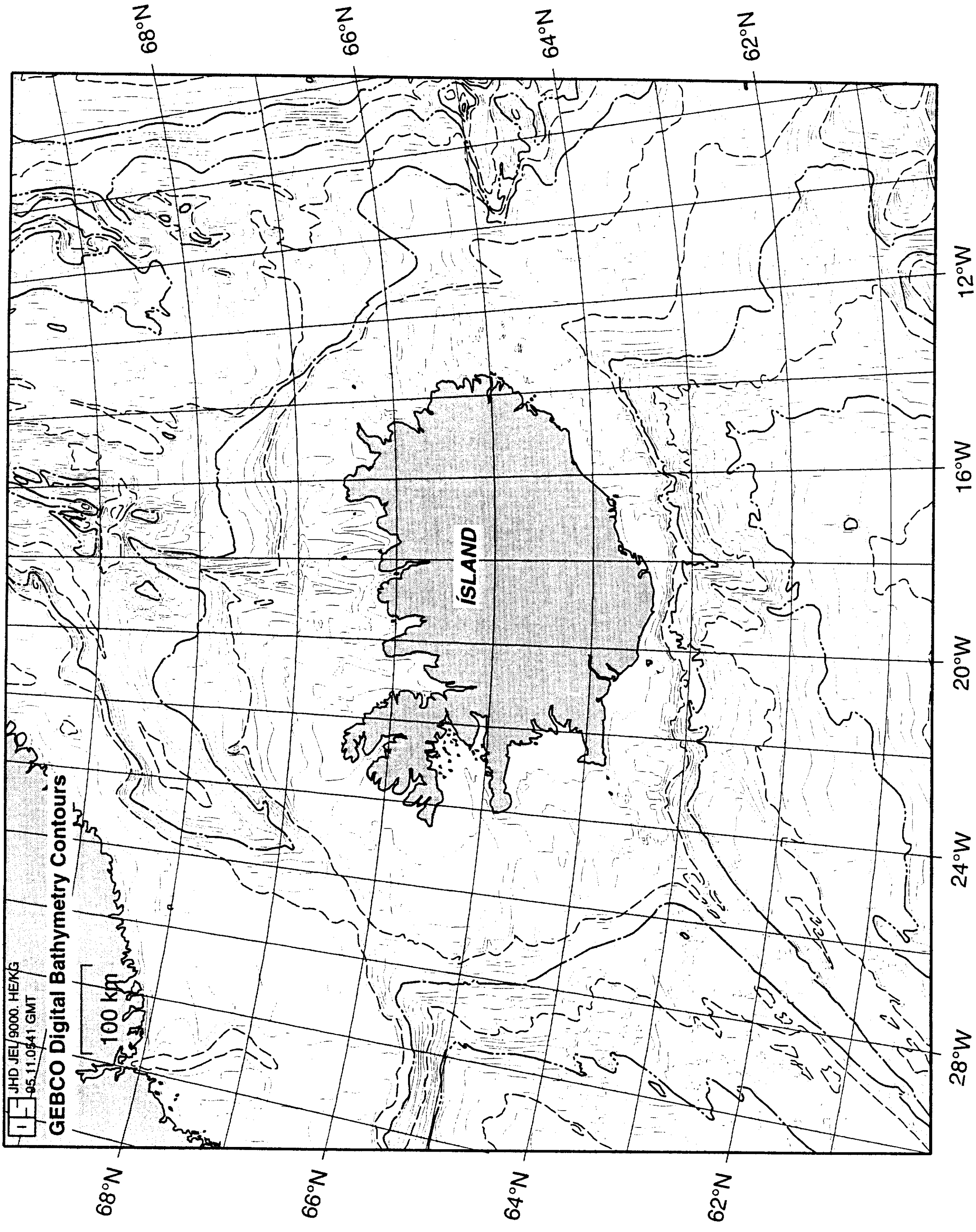


Figure 8. The GEBCO Digital Atlas bathymetric contours at 100 m intervals. Note that the 1000 m interval contours are labeled with dots, which number correspond to the thousands of meters. The 500 m contours in between are dashed. (This is a part of Gebco sheet 5.04 compiled by A.S. Laughton and D. Monahan).

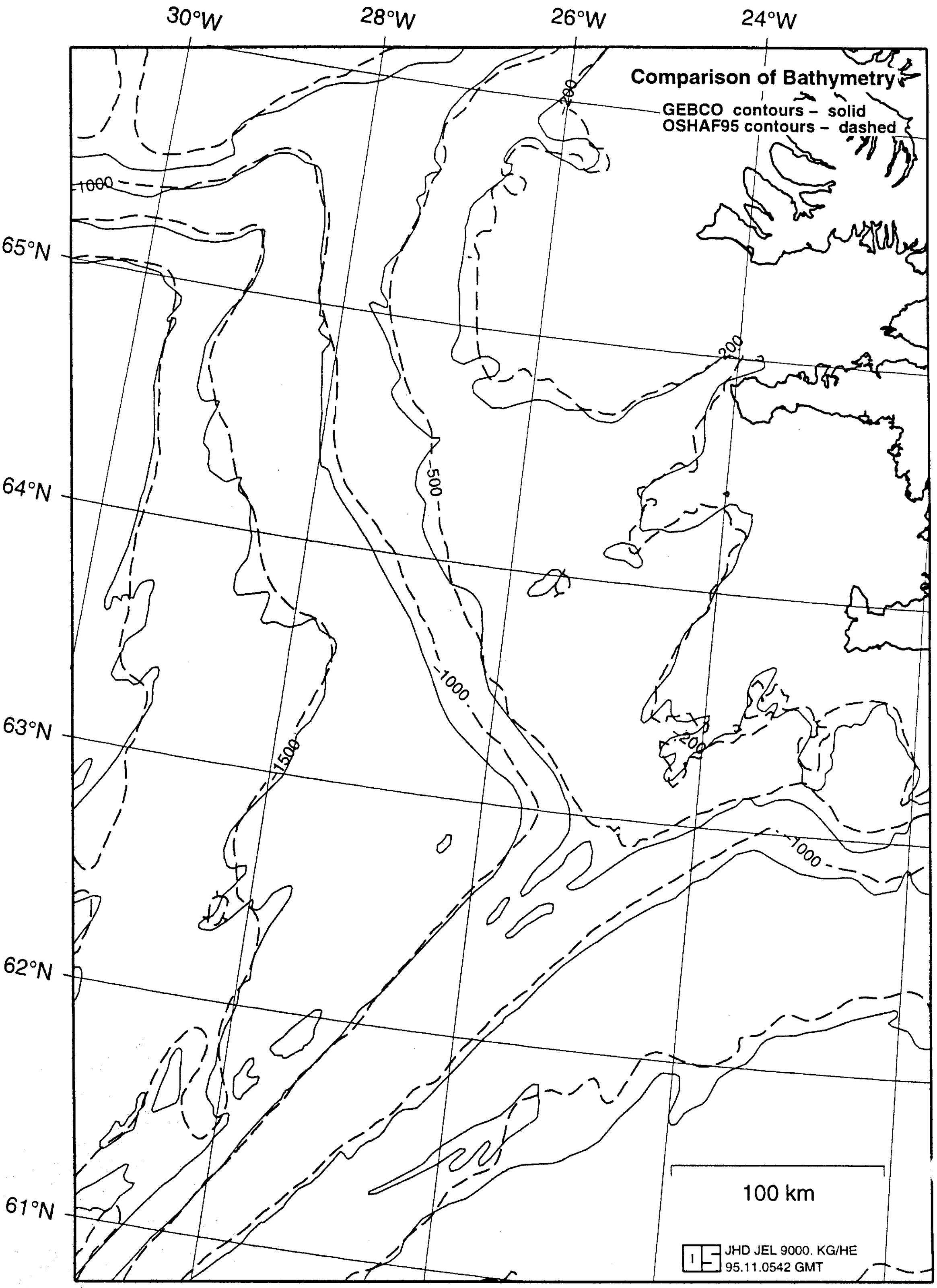


Figure 9. A comparison between selected GEBCO contours at 500 m intervals and corresponding contours from the present bathymetric compilation (OSHAF95), which are dashed and labeled.

4. MAGNETIC FIELD DATA

We include here a map of Total Field magnetic anomalies (Figure 10) based on various published compilations. The same map in scale 1:2,000,000 is shown in Plate 4. This map is designed to be complementary to the gravity map in demonstrating the broad magnetic features of the area, showing e.g. clearly the magnetic lineations along the submarine Reykjanes and Kolbeinsey Ridges to the south and north of Iceland, and the more confused magnetic signature over Iceland and the Faeroe-Iceland-Greenland transverse rise. It should be noted, however, that this map covers a somewhat smaller area than the gravity maps. In this process we have assembled a number of data bases or sets, which include both original survey line data and compiled regularly gridded data sets. However, the map is actually constructed using only two large gridded data compilations made available to us, except for a small area offshore NW-Iceland. We have not attempted to process the data in any way other than resampling to a new grid. The data can be sub-divided into gridded data and survey line data

4.1 Gridded data used for the map

Two large gridded data sets have been used for the construction of the map. They are based on a large amount of original line data that have been processed and interpolated to regular grids. These data forms are suitable for making computer maps, but the veracity is highly variable and depends upon the accuracy, compatibility and density of the primary data, and the interpolation algorithms. As these factors are not easily deduced from the presented data, care must be taken in the use of the map. The following data bases were employed:

1) DNAG-data

A large compilation of magnetic data was published in association with the series "The Geology of North America", a part of the "Decade of North American Geology (DNAG) Project" (see reference: Committee for the Magnetic Anomaly Map of North America, 1987). The original data include shipborne measurements and aeromagnetics. Through the intermediation of the Science Institute (Geirfinnur Jónsson) we have obtained a subset of this huge magnetic data grid, that covers the North-east Atlantic sea area around Iceland, contained within the extreme limits of about 58.16-71.27°N and 35.83-10.03°W, but does not cover the whole of this area. The digital data are with a grid spacing of about 2 km, and our subset contains some 280,000 points. These data are here referred as the "DNAG-data", and are used with the permission of the compilers.

In Figure 10 the extent of coverage in the dataset can be seen. The area covered is somewhat irregular and a number of gaps are seen. The largest gap is in fact the land area of Iceland, but this is covered by the Icelandic aeromagnetic data (see below). The original grid is defined in a Transverse Merkator projection centered on The American continent and is skew in the Iceland area. In this work we have resampled the data onto a 2 km grid based on the standard Iceland Conical Projection used for this report.

The anomaly values of the data set range from -6870 19304 nT. The extreme values are surely due to error, and some abnormally strong local anomalies are seen in the data north and east of Iceland, which are surely incorrect. They have a characteristic shape and could very likely be caused by spikes modified by a smoothing or gridding operator. These small areas have been blanked out in the map. (Abnormal positive anomalies at 67.15-67.36°N, 13.77-14.10°W and 65.88-66.08°N, 12.33-12.62°W, one abnormal point at ca. 64.5°N, 11°W, and a negative anomaly at: 66.15-66.26°N , 20.67-20.86°W).

2) Iceland Aeromagnetic data

Aeromagnetic surveys for Iceland have been conducted by the Science Institute, University of Iceland, and published by Leó Kristjánssonar et al. (1989) and Geirfinnur Jónsson et al. (1991). The flight lines are at 3-4 km spacing. Altitudes are about 900 m over lowlands but reach up to 2100 m over the highest ground. We have obtained 2-by-2 km gridded data from this source, which we have resampled according to the standard for this work. The data coverage extends a short distance offshore (the border is indicated in white in Figure 10) and overlaps the DNAG data except for a large gap west of Iceland, which has been filled with survey track data (see ch. 4.2).

4.2 Survey track data

Magnetic data were collected by ship for some part ofareas of the Iceland shelf during some the 1972-1973 gravity survey listed under the haeding NEA (sms_no) in Table 1. The magnetic data and data processing is descibed by Geirfinnur Jónsson et al. (1991). These tracks are at 10-13 km intervals. We have used those parts of these data that cover the northwest of Iceland shelf (offshore Breiðafjörður and Vestfirðir), for the purpose of filling a glaring gap btween the DNAG data set and the Iceland aeromagnetic data set.

The GEODAS marine database contains a considerable quantity of magnetic data along ship tracks, although the density is less than for the gravity and bathymetric data and in most areas insufficient for making a detailed map. Figure 11 shows the tracks of cruises from the GEODAS database where magnetics have been collected (some data gaps might exist along the lines). We have not used these data for this presentation, but some of these are probably included in the DNAG compilation described above.

An extensive low-altitude (150 m) aeromagnetic survey was carried out by the US Navy under the name Project Magnet north of Iceland, and published by Vogt et al. (1980). We obtained these data in 1995 in the form of total field digital data at 5 seconds intervals along survey lines, by the courtesy of F. Slade Barker, Director of Processing and Validation Department, Naval Oceanographic Office. The flight lines are displayed in Figure 12. These data are included in the DNAG compilation and are by far the best magnetic data coverage of the area north of Iceland.

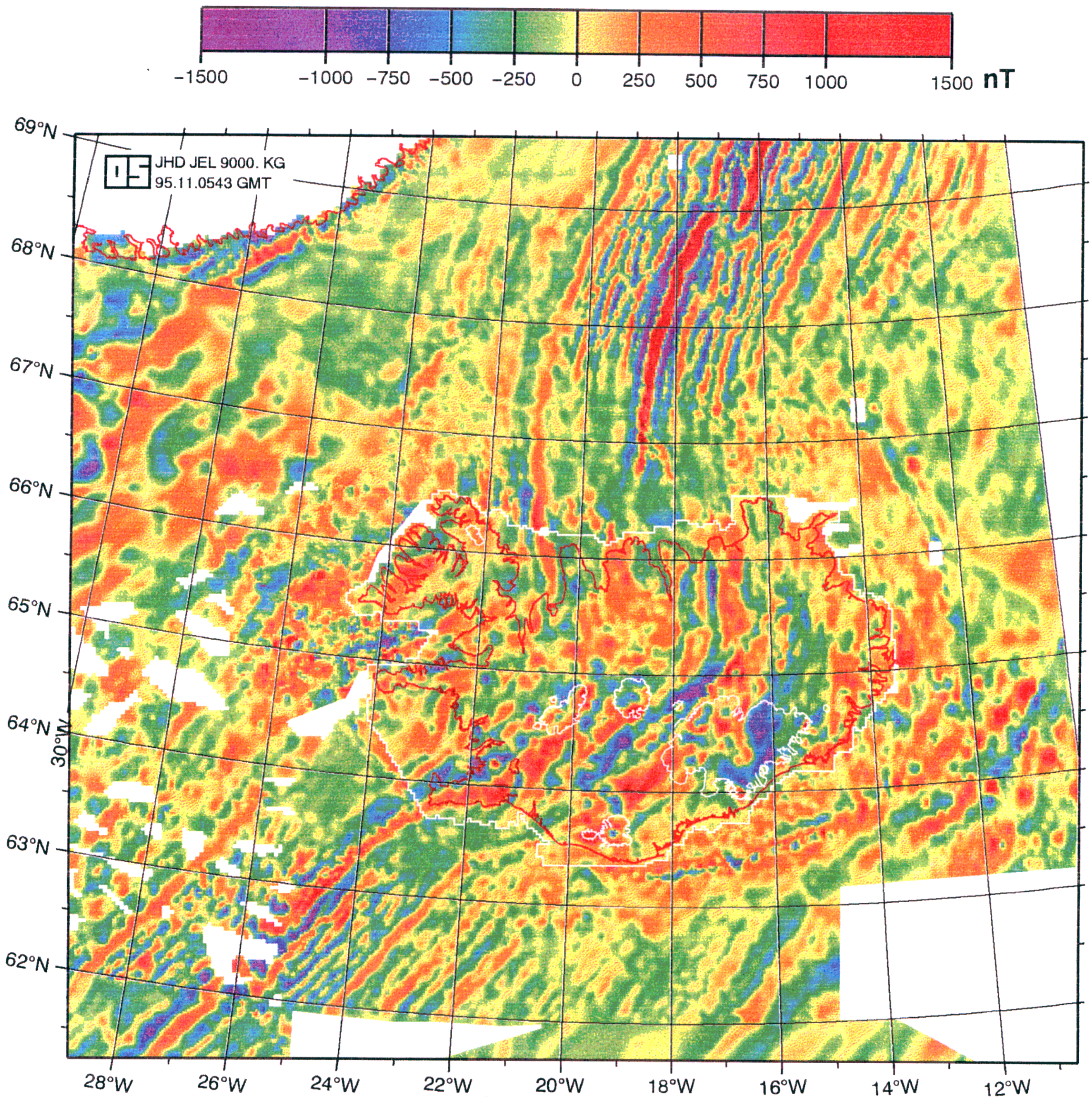


Figure 10. Total Magnetic Field Anomaly map based on the DNAG and Iceland aeromagnetic gridded data. The data is identical to the enclosed large scale map. The outline of the overlapping Iceland aeromagnetic data coverage is shown as a white line close to the shore.

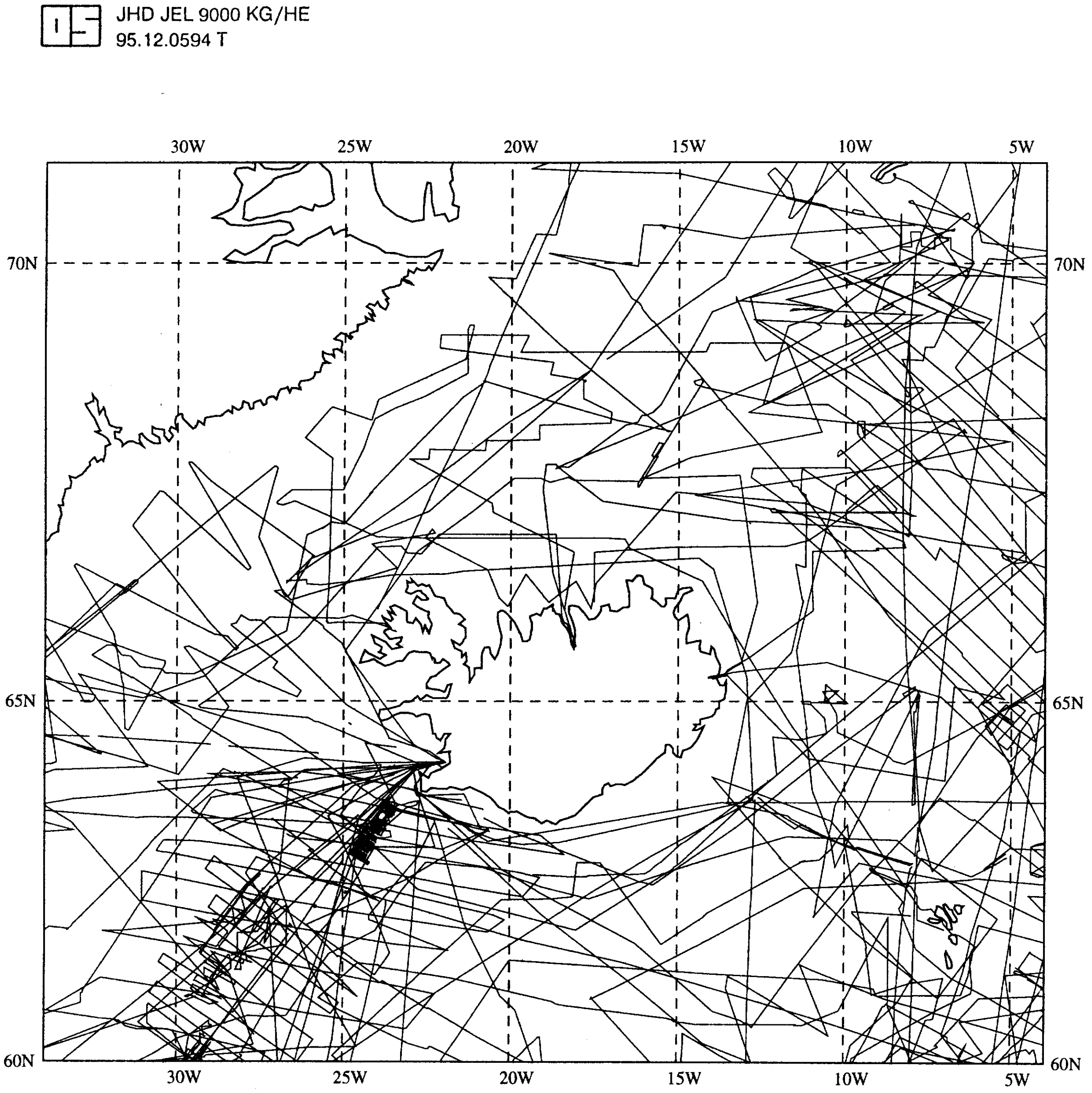


Figure 11. Ship tracks of the GEODAS data base, showing cruises including magnetic data.

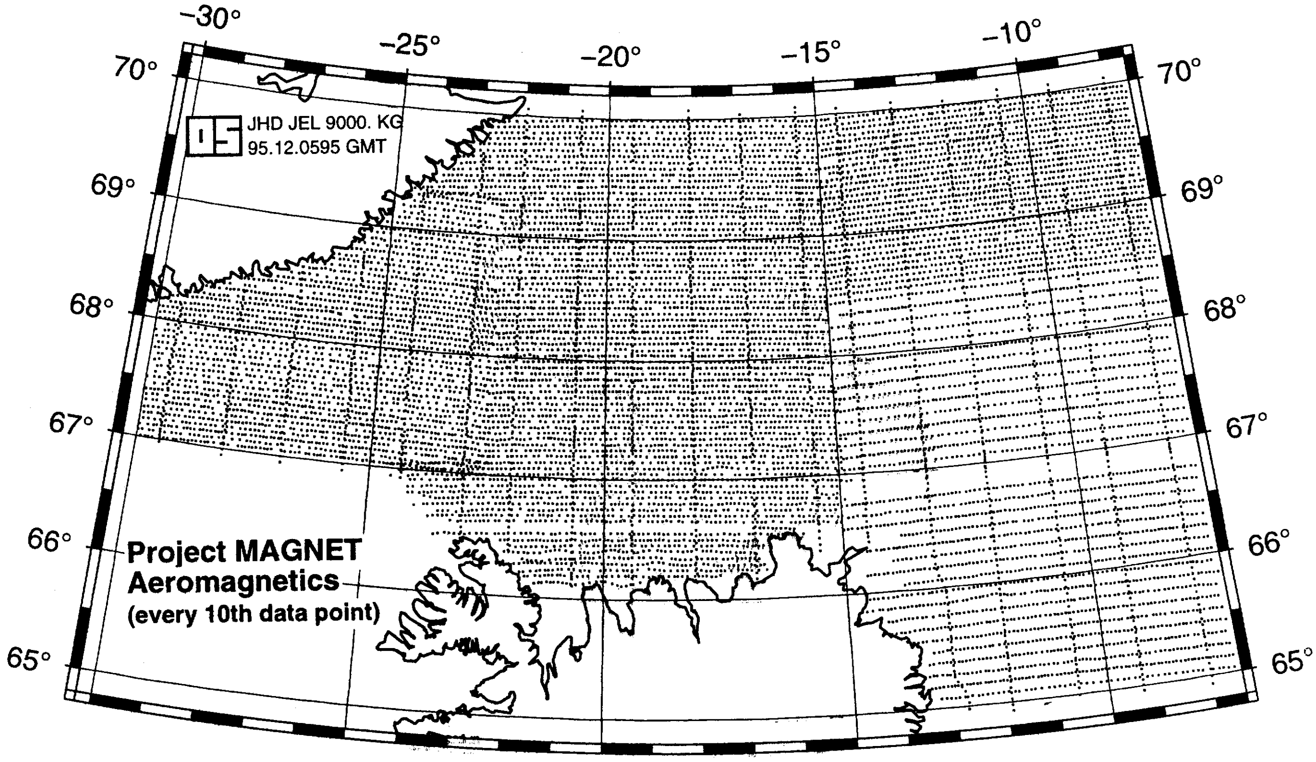


Figure 12. Project Magnet flight tracks north of Iceland are indicated by every 10th data point.

5. DATA AVAILABILITY

This report is distributed without the large scale maps (1:2,000,000), which are referred to as "Plates", comprising:

- Free-Air gravity anomaly
- Bouguer gravity anomaly
- Bathymetry/topography
- Total field magnetic anomaly

These maps are available on request for a modest price. The data files containing the gridded data used for the maps are also available.

The original data are of variable origin and status of propriety. Distribution of these must be subject to negotiation.

Request for maps and/or data should be made to the following addresses:
Orkustofnun, Grensasvegur 9, IS-108, Reykjavik, Iceland,
e-mail address of the authors is he@os.is and kg@os.is.

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7. ÚTDRÁTTUR

Skýrsla þessi fjallar um söfnun og úrvinnslu gagna um þyngdarmælingar af hafsvæðinu umhverfis Ísland úr skipa- og gervitunglamælingum sem þar hafa verið gerðar. Gögn af sjálfu landinu úr gagnasafni Orkustofnunar eru innifalin í þessu safni. Að auki hefur verið unnið úr dýptar- og segulmælingum á svæðinu. Úr þessum efnisgrunni hafa verið gerð þyngdarkort sem við teljum betri en önnur kort af þessu tagi, einkum fyrir landið og landgrunnið. Allar fáanlegar mælingar umhverfis landið frá skipum á vegum innlendra og erlendra aðila (tímabilið 1967-1985) hafa verið kannaðar, og þær nýttar sem taldar hafa verið næganlega nákvæmar og þéttar. Sumt af þessum gögnum hefur ekki áður verið nýtt í samræmd kort. Gögn hafa einnig bæst við á landi, einkum á jöklum. Víða á hafsvæðunum fjær landinu höfum við notað nýlegt alþjóðlegt þyngdarsvið sem er fengið með hæðarmælingum úr gervitunglum, og er nákvæmt að öðru leyti en því að skörpustu smáatriði í sviðinu eru sléttuð út. Þetta kemur helst að sök á grunnum svæðum þar sem góðar skipamælingar vantar, einkum á Reykjaneshrygg sunnan 63°N, á landgrunni Grænlands og yfir landgrunnshlíðum vestan Íslands.

Út frá þessum gagnagrunni hafa verið gerð kort af þyngdarsviðinu í mælikvarða 1:2.000.000, bæði með "Bouguer" þyngdarfráviki og "free-air" þyngdarfráviki. Kortin eru tölvuteiknuð í keiluvörpun Lamberts með miðju í landinu, og ná gróft á litið milli 32°-6°V, og 60°-70°N. Að auki hefur verið teiknað dýptar- og hæðarkort í sama kvarða á grunni tölræns landslagslíkans af svæðinu sem tekið var saman til að reikna leiðréttingar fyrir þyngdarsviðið. Inn í þennan grunn voru tekin ýmis hæðargögn af landinu, dýptarmælingar úr skipamælingunum og hinn alþjóðlegi gagnagrunnur ETOPO5. Þetta er að líkindum með betri fánlegum söfnum tölrænna dýptarmælinga umhverfis landið, og dýptarkortið reynist vera þokkalega nákvæmt í samanburði við sjókort og hið alþjóðlega "GEBCO Digital Atlas" sem inniheldur tölræn dýptarlínukort.

Til að fullkomna "settið" var gert segulkort af svæðinu, byggt á samantekt flugsegulgagna frá Háskóla Íslands, og safni mæligagna amerískra aðila ("DNAG" útgáfa) af hafsvæðunum. Kortaserían er fáanleg hjá Orkustofnun fyrir lágmarksgjald, og tölrænu netgögnin, sem kortin eru dregin eftir, eru einnig fáanleg.