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GRAVITY MEASUREMENTS ON SUMMER SEA ICE IN THE BEAUFORT AND CHUKCHI SEAS, 1976

By

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During September, 1976, a series of gravity measurements was made in the western Beaufort Sea and the northern Chukchi Sea on ice floes and on a grounded ice island. The data were taken to evaluate the technique of measuring gravity on small ice floes in summer and to supplement and extend previous measurements in the area. The locations of the gravity stations are shown on the map, which also shows previously published data taken by ship-borne gravity meters in the same general area taken from Ruppel and McHendrie(1976) and Boucher et al.(1977). Seventeen gravity stations were occupied during a 26-day cruise aboard USCGC Glacier.

Weather conditions at that time restricted helicopter flying time to one or two days each week when the ship operated near the ice. In one day in the course of 3 helicopter sorties, 9 measurements were taken along a line at distances up to about 116 km from the ship. On 5 occasions an observer was placed directly on the ice from the icebreaker, which was "beached" for the purpose on a grounded ice island or on large ice floes.

Gravity measurements were made with a geodetic gravity meter (LaCoste & Romberg meter G-426). The aluminum base plate was placed either on a wooden tripod in snow or directly on the ice of frozen puddles. Air temperatures were in the range -7.5 to +2.0 C. For safety's sake only solid-looking ice floes with a least horizontal dimension of 50 m or more were chosen as helicopter landing sites. The ice was generally 1 to 2 m thick at the edges of the floes. After the observers embarked on the ice, the helicopters withdrew to a distance of about 500 m to eliminate their noise and vibration. Depth measurements at stations A to C were made by firing a blasting cap in the water and measuring the bottom reflection time with an engineering seismograph, using a hydrophone suspended in the water at the edge of the ice. At stations M to O, depths were determined from the ship's fathometer, located within about 50 m of the observation point.

Ice motion is the principal limiting factor on the precision of the measurements. Conditions appeared to be quietest within essentially ice-covered areas, when the floe used for the measurement was discontinuous with the surrounding ice and there was little or no wind. Swell was usually found to be small in ice covered areas. Under these conditions the gravity meter was quite stable and could be read repeatably to better than +/- 0.1 milligal. Under poorer conditions, particularly with moderate wind, up to 15 km/hr, the gravity meter did not settle down and the accuracy of reading was degraded to as much as +/- 2 mgal.

Location of gravity stations was by range and bearing, determined by air-search radar, from the ship, whose position was determined by satellite navigation. The combined effects of uncertainty in ship's position (assumed to be less than 1 km at worst) and accuracy of radar fixes are estimated to yield a maximum uncertainty of about 5 km in station locations at the maximum range of about 116 kmfrom the ship and proportionally less at shorter ranges.

The 1976 data stations are shown on the map, which places them in context with earlier shipborne measurements. The map is divided into two parts. West of 157 W., where available data are much more sparse, the new data are simply superimposed upon the contours of Ruppel and McHendrie (1976). The additional data in this region are too few in number to justify recontouring, but they indicate that more data are urgently needed to characterize the gravity field adequately. Of possible significance are the data stations M, N, and O. These were made on an ice feature variously known as "Katie's floeberg", or perhaps more descriptively as the "Hanna shoal grounded icefield" (Toimil and Grantz, 1976.) In that paper the Hanna shoal, which lies on the westward extension of the Barrow Arch (Grantz et al., 1975) is described as being structurally controlled, possibly representing an outcrop of early Cretaceous or older rocks which are known to extend to, or very near, the seafloor. The relatively large values of free-air anomaly observed at the grounded icefield, up to 88 mgal, strongly support the notion that the Hanna shoal may be the bathymetric expression of an anticlinal structure in which older, denser rock is located at a relatively shallow depth beneath the seafloor. In view of the semi-permanent nature of the grounded icefield, it is suggested that it could be used as a base station for future gravity studies in the northern Chukchi Sea.

East of 157 W., the shipborne gravity coverage is considerably more dense than to the west, and the 1976 gravity data were used in preparing the free-air contour map.

Stations J, M, and Q were located near the sites of previous gravity measurements by the U.S.G.S. using a ship-borne gravimeter system aboard USCGC Burton Island in 1972 and 1973 (Ruppel and McHendrie, 1976). Point J appears to be compatible with the nearby data collected in 1973. Points M and Q appear to be 5 to 12 mgal higher than values recorded in 1972 aboard Burton Island, although as can be seen from the map the data were not collected at precisely the same locations, precluding an exact comparison. There is thus a suggestion that the base level of the 1972 observations may differ from the 1973 observations and those reported here by approximately 10 mgal, in the sense of being low.

Land ties at Barrow, Alaska, at the beginning, middle, and end of the cruise indicated a change of baseline due to combined effects of gravity meter drift and possible tares of approximately 3 mgal over a period of 27 days. A parabolic curve was fitted to the land tie data in the absence of information about possible tares. The higher-than-normal drift rate is very likely due to the effects of vibration experienced by the gravity meter on board ship and during helicopter operations.

The data table lists the individual gravity stations, measured gravity, free-air gravity anomaly according to both 1930 and 1967 reduction formulas, estimates of accuracy, and water depth when available.

In future operations it would be advantageous to use a gravity meter of somewhat reduced sensitivity and with a higher degree of damping than G-426, since conditions did not permit effective utilization of the 0.01 mgal sensitivity of that meter. Due to the long intervals between land ties that are likely during ship-based operations, the gravity meter used requires a very small or very predictable drift rate to achieve accuracy of 1 mgal or better, which should be expected in the current state of the art in the offshore Arctic.

The general success of the operation, coupled with the convenience of working in mild summer weather, indicates that the technique of working on small ice floes is a useful way of obtaining gravity data in ice-covered waters.

Acknowledgments

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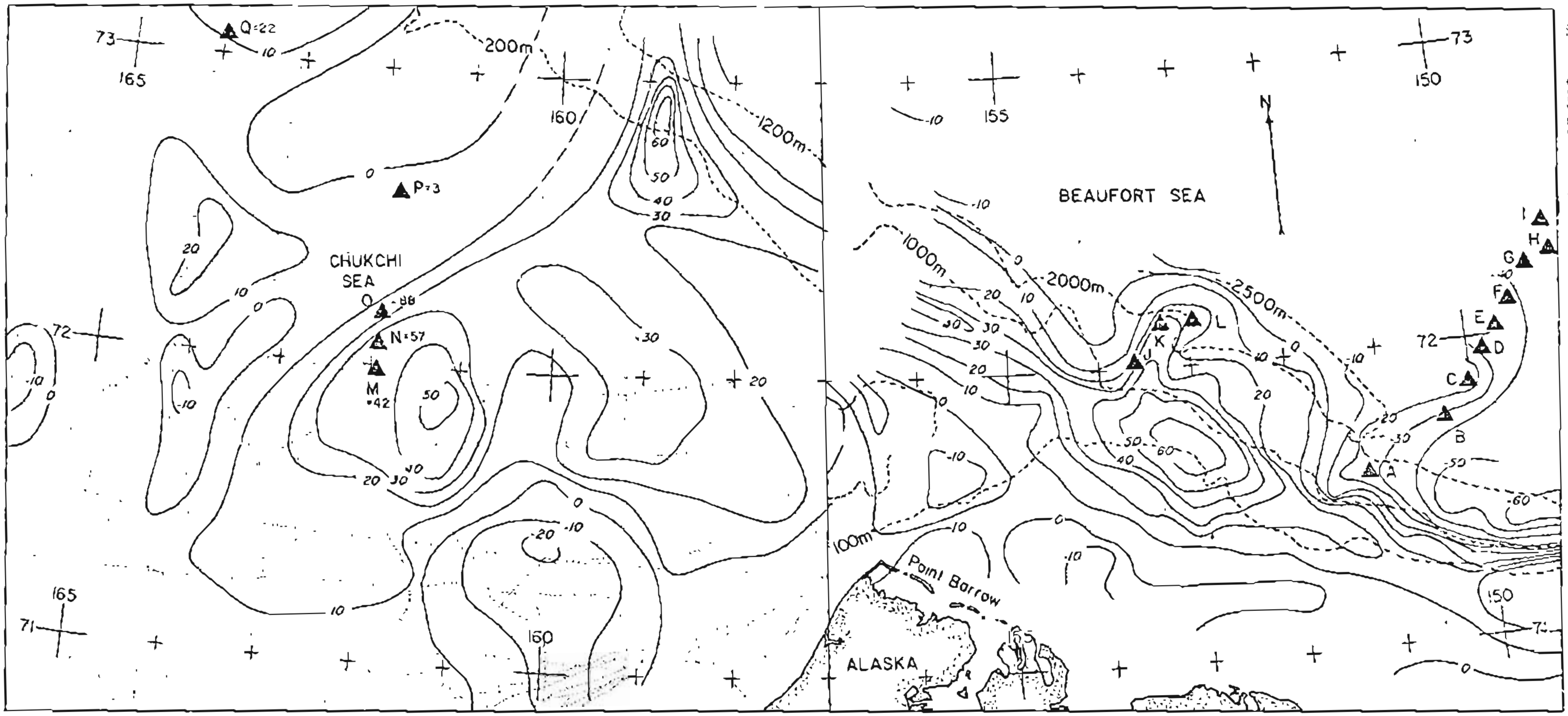

POLAR STEREOGRAPHIC PROJECTION

0 50 100

KILOMETERS

FREE-AIR GRAVITY ANOMALIES ACCORDING TO 1930 INTERNATIONAL GRAVITY FORMULA

10 MILLIGAL CONTOURS, FREE-AIR GRAVITY

ISOBATHS, METERS, AS LABELLED

SHIP TRACKLINES, 1972-1974

GRAVITY STATIONS ON ICE, 1976

M=42 FREE-AIR GRAVITY ANOMALY AT A STATION, MILLIGALS

NOTES:

1. WEST OF 157° LINE, 1976 DATA ARE NOT INCORPORATED INTO THE CONTOURING. DATA VALUES ARE SHOWN. CONTOURS & TRACKLINES FROM RUPPEL ET AL., 1976.

2. EAST OF 157°, 1976 DATA WERE USED IN THE CONTOURING. CONTOURS FROM BOUCHER, ET AL., 1977.

INDEX MAP

TABLE OF DATA

MAP DESIGNATION	LATITUDE °N	LONGITUDE °W	POSITION ERROR, KM	GRAVITY, MGAL	FREE-AIR ANOMALY, MGAL IGF1930	GRS1967	PRECISION MGAL	WATER DEPTH, METERS
A	71.59	151.20	.5	982689.37	-13	-8	.05	1530
B	71.75	150.32	2.	982679.69	-31	-27	0.1	2450
C	71.86	150.03	2.5	982690.81	-26	-21	0.1	2784
D	71.96	149.84	2.5	982691.44	-31	-26	0.1	NA
E	72.03	149.66	3.	982691.31	-34	-30	0.1	NA
F	72.11	149.48	3.	982692.37	-38	-34	0.01	NA
G	72.22	149.23	3.5	982690.62	-44	-40	0.1	NA
H	72.26	148.95	4.	982691.37	-47	-42	0.05	NA
I	72.36	148.88	5.	982698.19	-45	-41	0.1	NA
J	72.02	153.57	2.	982759.56	+34	+39	0.5	NA
K	72.14	153.29	2.5	982764.87	+34	+38	0.2	NA
L	72.15	152.95	3.5	982755.50	+23	+27	0.2	NA
M	71.99	161.94	0.5	982765.5	+41	+46	0.1	21
N	72.08	161.91	0.5	982785.87	+57	+62	2.0	30
O	72.18	161.89	0.5	982822.19	+88	+92	0.1	36.5