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COMMENTS ON THE MAP OF FREE-AIR GRAVITY ANOMALY OF THE ANTARCTIC REGION

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Abstract: A free-air gravity anomaly map of the Antarctic region was published in 1984 as Special Map Series of National Institute of Polar Research, No. 3. In this paper some comments are given as to data distributions for compiling the map and characteristics of the gravity anomaly shown in the map, so that the map may be properly referred to.

1. Data Distribution

A map of free-air gravity anomaly of the Antarctic region was published in 1984 as special map series No. 3 of the National Institute of Polar Research, Japan (SEGAWA *et al.*, 1984). The data used to compile the map are from the following four sources:

(1) Land gravity data of about 7000 points measured in Antarctica. This included the data of the International Gravimetric Bureau of Paris (IGB, 1974), Russian data compiled by GROUSHINSKI *et al.* (1972) and the data of the Japanese Antarctic Research Expeditions. Gravity data in New Zealand (NZDSIR, 1979) were partly used. Data for the southern end of South America were not available.

(2) Marine gravity data from the measurement by the NIPRORI-1 sea gravimeter of icebreakers FUJI and SHIRASE during the Japanese Antarctic Research Expeditions from JARE-21 to JARE-25, the measurement by an Askania sea gravimeter of USNS ELTANIN, and part of the measurement of R.V. HAKUREI-MARU of the Japan Ministry of Trade and Industry by a LaCoste-Romberg sea gravimeter.

(3) Gravity-converted satellite altimeter data of GEOS-3 up to 65°S.

(4) Gravity-converted satellite altimeter data of SEASAT-1 up to 72°S.

The areal distribution of gravity data used is shown in Fig. 1. Land gravity data are on the tracks in the Antarctic continent where traversal measurements were made. Although not indicated in the figure the point data of the International Gravimetric Bureau and GRUSHINSKI's files are distributed inside the continent.

Distribution of marine gravity data is along the ship's tracks in Fig. 1. The data from 0° to 90°E are mostly of the measurement by the Japanese Antarctic Research Expeditions, and those from 90°W to 180° are from the measurements by USNS ELTANIN and the HAKUREI-MARU.

Satellite altimeter data are distributed along the satellite tracks. Spacings of altimetric data are approximately 7 km along the tracks. This is dense enough, but as

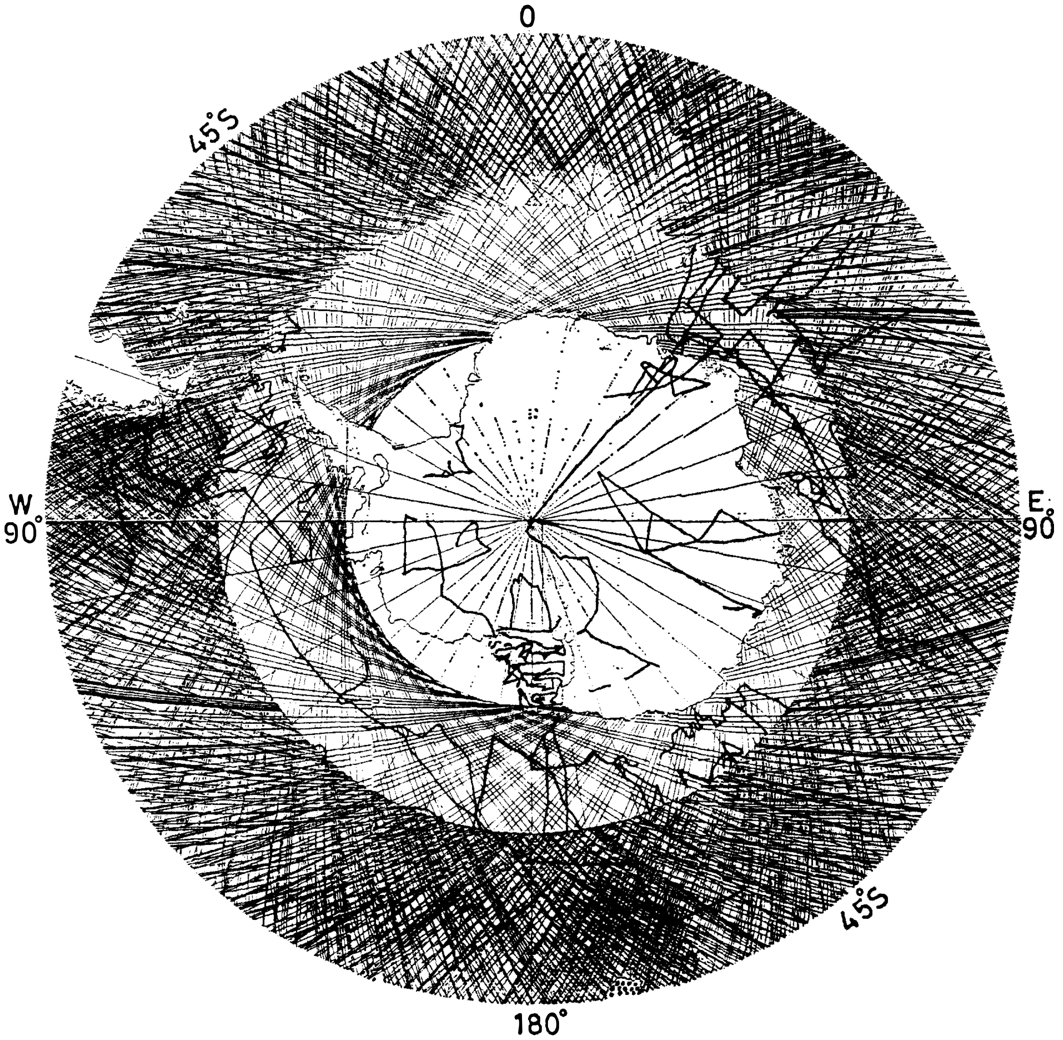

Fig. 1. Areal distribution of gravity data used. Tracks of thick solid lines in Antarctica show the location of land gravity data. Although not indicated in the figure more point data of gravity exist inside the continent. Tracks of thick solid line at sea are the location of surface ship gravity data. A dense net of satellite tracks is the place where dense altimetric geoidal data exist. Up to 65°S there are data of both GEOS and SEASAT, and south of 65°S only the SEASAT data are available. A small amount of data in the southern tip of New Zealand are found at nearly 170°E. No data are available in the southern end of South America.

seen from Fig. 1 the spacings between the tracks are a few tens of kilometers in some part in the area between 65° and 72°S. Raw altimeter data of GEOS-3 and SEASAT-1 involve large orbital errors. The raw data are the sea surface height above the earth ellipsoid. Sea surface height was corrected for ocean dynamical effects, *i.e.*, oceanic tide and wave, to get a surface which is close to geoid. In the area where icebergs were distributed the sea surface showed irregular features with the amplitude of ± 3 m. This has been filtered out using a proper lowpass filter (MATSUMOTO *et al.*, 1985). The geoid thus obtained is converted to gravity anomaly by means of two-dimensional Fourier series method.

Contouring of gravity anomaly was made on the basis of $10' \times 10'$ block means of gravity anomaly. Altimeter data were offered by JPL (Jet Propulsion Laboratory, California Institute of Technology) and Dr. R.H. RAPP of the Ohio State University.

When the gravity anomaly given by this map is interpreted it is important to take the density of gravity measurement into account. Land areas, in particular, are the place where the data are the sparsest, and the icy area in the Weddell Sea and the Ross Sea which satellites did not reach is also lacking in data. In spite of the zones where the data are missing the gravity anomaly contours were smoothly drawn by means of a two-dimensional interpolation technique.

2. Nature of Gravity Anomaly Obtained

Although the published map is named the map of free-air gravity anomaly, it is not a correct expression. Two kinds of gravity anomaly, *i.e.*, 'free-air gravity anomaly' and 'gravity disturbance', were indiscriminately used. Gravity anomalies obtained on land or at sea is the free-air gravity anomaly which is defined as,

$$\text{Free-air gravity anomaly} = \text{measured gravity} + \text{free-air correction} - \text{normal gravity}.$$

Free-air correction is the correction for elevation of the measuring site, by which the gravity anomaly is reduced to a value on geoid. Note that 'elevation' is defined as a height above geoid. If the height is measured from the surface of the earth ellipsoid and the free-air correction is made using the height the gravity anomaly is reduced to a value on the earth ellipsoid. Gravity anomaly according to the latter definition is named gravity disturbance. This can be formulated as,

$$\text{Gravity disturbance} = \text{measured gravity} + \text{correction for the height of measurement above ellipsoid} - \text{normal gravity}.$$

Gravity disturbance is, therefore, free-air gravity anomaly on the exact surface of the ellipsoid.

In order to convert geoid to gravity anomaly it was represented by the values on two-dimensional planes approximately (MATSUMOTO *et al.*, 1985). The earth is approximated by a polyhedron with planes of a proper size. A unit plane is nearly $10°$ by $10°$ in size. Altimetric geoid data that were defined on a plane were then Fourier-transformed to convert geoid to gravity anomaly. This conversion is, in principle, referred to the surface of the ellipsoid, resulting in deriving gravity disturbance. A difference between free-air gravity anomaly and gravity disturbance varies with the height of geoid. This difference ranges between ± 10 mgal as a rough estimation.

In the case of the present gravity map free-air gravity anomaly and gravity disturbance were not discriminated, and they were handled together to get a contour map. Contouring was conducted using BRIGGS' four-dimensional curved surface interpolation (BRIGGS, 1974).

3. Filtering and Wavelength of Gravity Anomaly

Gravity anomaly derived from geoid by means of Fourier-transform method is likely to be exaggerated in short wavelength components, particularly in a part where

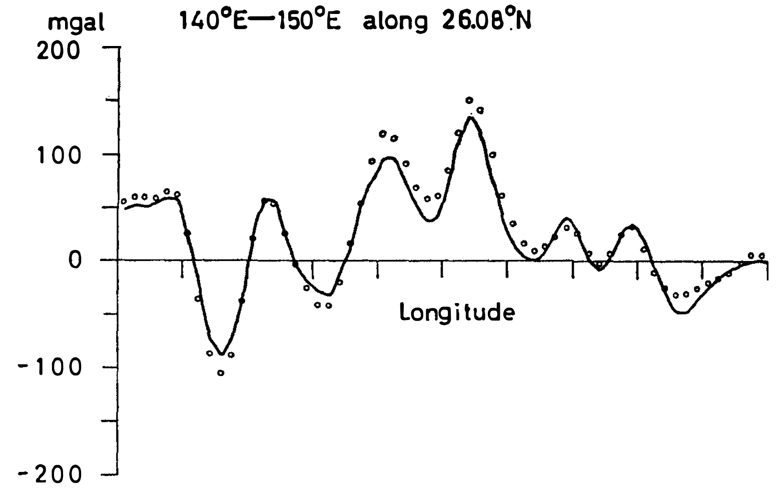

Fig. 2. Comparison between the surface ship gravity anomaly profile (open circles) and the geoid-converted gravity anomaly (solid line) along 26.08°N. Note that the geoid-converted anomaly is smoothed so that the anomaly differs by 10 to 20 mgal in the area where a sharp change of gravity anomaly occurs.

short wavelength errors are involved in the estimation of geoid. In order to reduce such false components low-pass filtering was applied to some extent to geoid data before applying the Fourier transform. A digital filter used for this sake has a form of an error function as $\exp\left(-\frac{1}{2}\frac{r^2}{D^2}\right)$. When D is taken to be 10 nautical miles, the transfer function of this filter is

$$S(\omega)=S(2\pi/\lambda)=S(0)\exp[-(44.42/\lambda)^2].$$

This equation means that the geoid undulation with a wavelength shorter than 44 nautical miles has undergone a significant attenuation. For the purpose of examining the effect of filtering on gravity anomaly two profiles of gravity anomaly are compared in Fig. 2. These profiles are along 26.08°N between 140° and 150°E. In the figure the open circles show the surface ship gravity anomaly and the solid line shows the altimetric gravity anomaly.

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