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TREND ANALYSIS OF GRAVITY AND TOPOGRAPHIC DATA IN THE ANTARCTIC REGION

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Abstract: Trend analysis method is quite popular in the study of digital image processing. The method is applied to the Antarctic geophysical data such as bedrock topography, gravity anomaly and thickness of ice sheet. The grid data derived from these geophysical observations and simple procedures of numerical derivatives and plotting clearly express the characteristics of geological structures: plate boundaries such as mid-oceanic ridge crests, boundaries of oceanic and continental blocks, which are useful for interpretation of tectonics in the Antarctic region.

1. Introduction

Recently precise topography and gravity maps were compiled (SEGAWA *et al.*, 1984) with the aid of the increase of measurement both on land and at sea, or development of technique of utilization of satellite altimeter data (MATSUMOTO *et al.*, 1985). Production of contour maps of topography and gravity anomaly, bird's eye view (block diagram), wave number analysis of topography and gravity anomaly are the conventional use of these digital data. On the other hand, these data are useful for extraction of lineaments to detect the tectonic structures by use of the trend analysis method. In this article, the authors will introduce some of the procedures of trend analysis using the geophysical grid data and show some examples of the application to the topography and gravity data used for the above-mentioned precise maps.

2. Extraction of Lineaments Using the Digital Data

Edge detection procedures in digital image processing are applicable to the analysis such as extraction of the lineament of tectonic structure and prediction of faults based on the digital topography and gravity data (HAGIWARA, 1986). These characteristics are exaggerated and clearly expressed by calculating numerical derivatives. In case that the derivatives are to be obtained strictly from these geophysical values, projection from the spheroidal earth onto its tangential plane must be taken into account. For the purpose of expressing the characteristics of these values, however, quite simple procedures are enough as usually used in digital image processing.

Provided that the size of the grid is 1×1 and that the value of the grid in the order of (i, j) is d_{ij}, then calculating, for example, gradient (first order derivative) as

$$\frac{1}{2}\sqrt{(d_{i+1,j}-d_{i-1,j})^2+(d_{i,j+1}-d_{i,j-1})^2}$$

Laplacian (same as mean curvature; second order derivative)

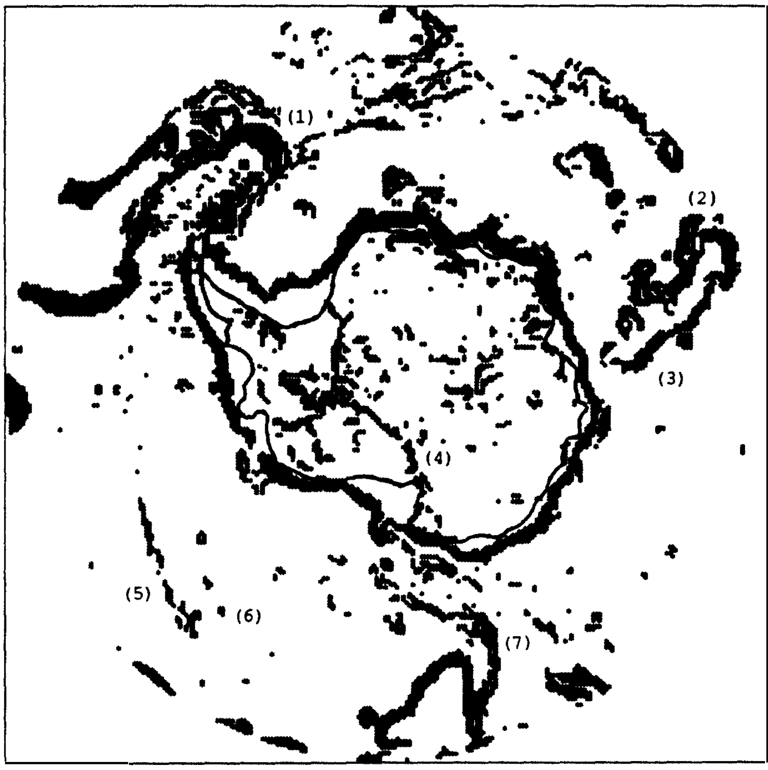
$$d_{i+1,j}+d_{i-1,j}+d_{i,j+1}+d_{i,j-1}-4d_{i,j}$$

torsion

$$\frac{1}{4}(d_{i+1,j+1}-d_{i-1,j+1}-d_{i+1,j-1}+d_{i-1,j-1})$$

and plotting the position where these derivatives are high would give the information about the tectonic structures. Generally, the higher order derivative exaggerates short-wavelength components and can provide useful information for detection of hidden geological structures. However, it is to be noted that adequate filtering is required before calculation of numerical derivatives in order to remove the effect of noises in the observed data.

The grid data used in this work are the same as those used for compilation of the gravity map (SEGAWA *et al.*, 1984). That is, altimetric gravity data in the ocean area and on-land measurement data are used. As for topographic data, basement rock



(1) *South Sandwich Trench*
(2) *Kerguelen Plateau*
(3) *Gausberg Plateau*
(4) *Transantarctic Mountains*
(5) *Eltanin Fracture Zone*
(6) *Udintzev Fracture Zone*
(7) *Hjort Trench*

Fig. 1. Gradient map of topography in the Antarctic region (south of 45°S). Bottom topography in the oceanic area, and basement topography in the land area.

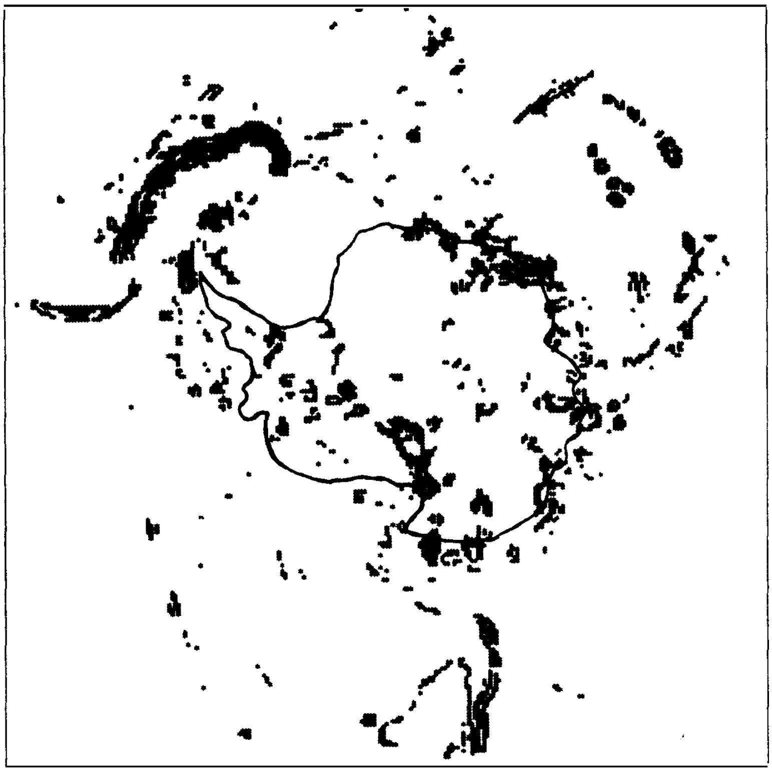


Fig. 2. Gradient map of free air gravity anomaly in the Antarctic region. Remarkable high-gradient zones are Queen Maud Land, Transantarctic Mountains, South Sandwich Trench, Hjort Trench, Eltanin and Udintzev Fracture Zones.

topography on land area (1/10000000 Karta Kornnogo Relyefa Antarktidy, 1975) and bottom topography data (GEBCO map) are digitized and compiled. The data in the whole area south of 45°S was projected onto a plane by polar stereographic equation of projection, and the projected plane was divided into 250×250 grids. Therefore, the size of each grid is about 40 km along the X and Y axes on the projected plane.

Figure 1 shows the result of the point of high gradient of topography in the Antarctic region. Figure 2 shows that of free air anomaly. High gradient zone of the Antarctic Peninsula, trenches around the Ross Sea, Queen Maud Land and Transantarctic Mountains are clearly shown in both of the two figures. The gradient map of topography (Fig. 1) expresses the coastal line of Antarctica, which is the narrow and steep area of the continental shelf.

3. Automatic Drawing of Water Flow Line, Topographic Direction and Shape

Water flow line is used for detection of water flow pattern in the field of land geography. For automatic calculation using the topographic grid data, it should be assumed that water flow occurs in the direction of the steepest downward slope. Then the procedure is: first, the neighbouring point of the steepest downward slope is detected by 8-direction scanning, and secondly, the two points for all the sets should

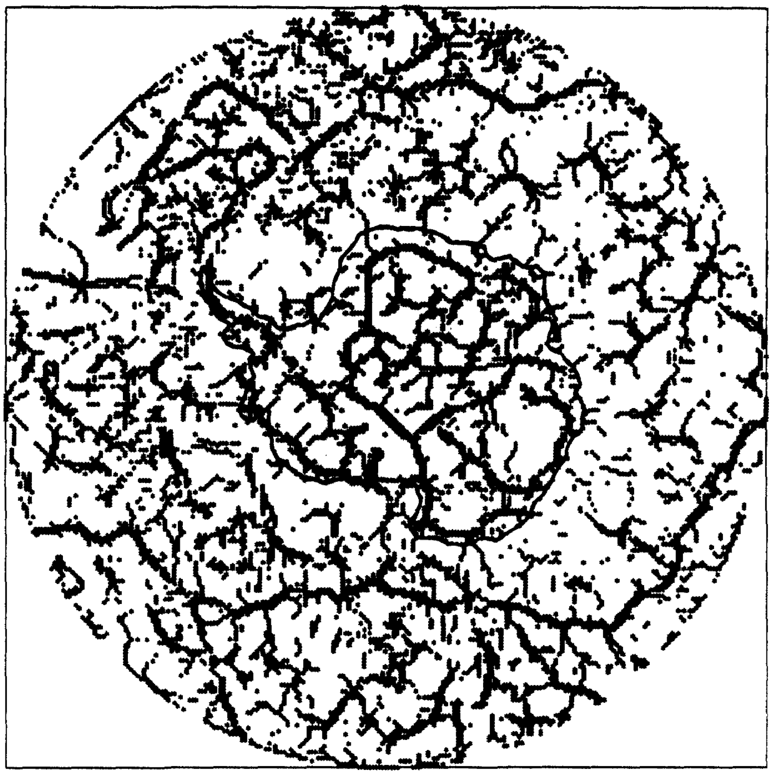


Fig. 3. Trend of ridge crests based on the calculation of water flow line.

be connected to make water flow lines (NOGAMI, 1985).

Calculation of the accumulated water volume by use of the water flow line and plotting the point of larger volume than a certain threshold value make a chart showing the lineation of depressional topography such as troughs and grabens. When plotting is carried out as for the points of no flow-in, then the chart expresses lineations oı ridges.

Figure 3 shows an example: Trend of the ridge crest based on the bedrock topography data (ocean area; bottom topography, land area; basement topography). This shows, for example, the lineations of the following topographic feature.

(1) The Transantarctic Mountains form a quite different range from that of the Antarctic Peninsula Group.

(2) The Transantarctic Mountains have a junction point of topography at 84°S, 160°E, and another mountain range extends to the Princess Elizabeth Land from this point.

(3) The Kergueren Plateau (50°S, 70°E) extends from NW to SE, whereas the Gaussberg Plateau just south of it extends from NNW to SSE.

(4) Antarctica is surrounded by the Pacific-Antarctic Ridges and other ranging topographic highs.

(5) The offset of crests of the East Pacific Rise due to the existence of Eltanin and Udintzev Fracture Zones is clearly recognized.

Figure 4 shows an example of application to the topography of ice sheet. It shows the expected ice flow due to the height difference of the ice sheet between the

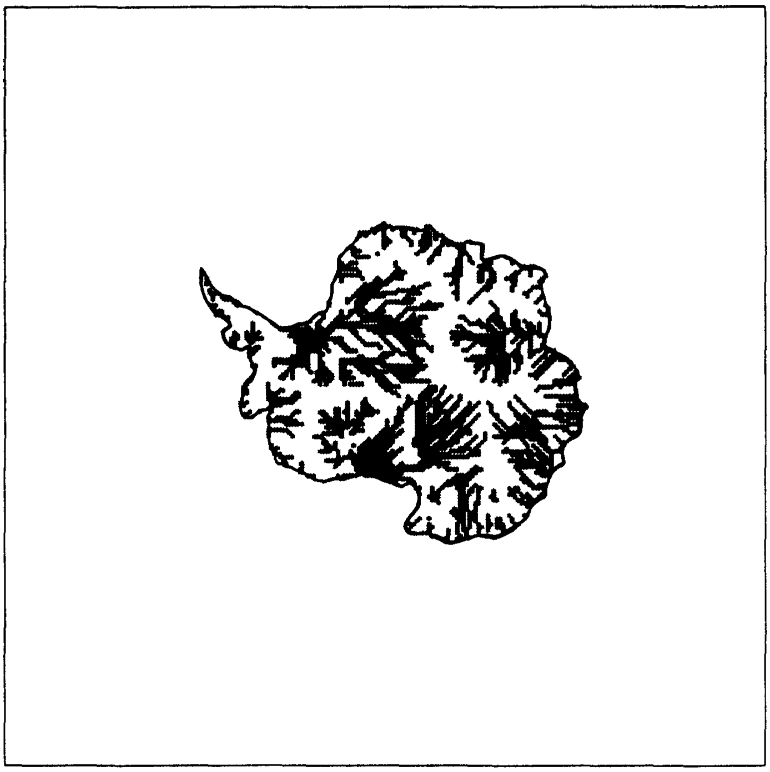


Fig. 4. Trend of depression of the surface of the ice sheet based on the calculation of water flow line.

neighboring points. Such an ice flow diagram with manual drawing is published (BUDD *et al.*, 1971). The method presented in this article enables us to calculate the direction of flow and to draw it automatically by electronic computers.

Figure 4 shows that in West Antarctica the area of ice flow volume is larger than that in East Antarctica. The flow pattern of ice suggests the areal difference of formation of ice shelves; large amounts of ice shelves such as Ross, Filchner and Ronne in West Antarctica.

4. Conclusion

The trend analysis conducted so far is likely to be dependent on the subjectivity of man. However, quantitative and objective trend analysis has become available by use of electronic computer and processing large amounts of digital data in a short time. As for bottom topography, precise local survey is conducted by use of SEABEAM, and a trend analysis based on the precise topographic data is now in progress. As for the Antarctic land area, for example, around Syowa Station, survey points are now increasing (although local). So, analysis with higher quality can be conducted as the data increase.

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