JOURNAL OF GEOPHYSICAL RESEARCH VOL. 68, NO. 16 AUGUST 15, 1963

Automatic Mapping of the Geomagnetic Field[1]

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Abstract. Spheric harmonic representations are used to illustrate the application of the U. S. Weather Bureau machine-mapping system for drawing charts of the geomagnetic field. This technique is also applied to the representation of model S_q fluctuations by maps of electric current flow in the ionosphere.

J. Geophys. Res., v. 68, no. 16, Aug. 15, 1963, pp. 4689-4696

Introduction. The purpose of this note is to discuss the application of the field-contouring techniques developed at the U. S. Weather Bureau to the illustration of the geomagnetic field and its time changes. This study, an outgrowth of the work with Vanguard 3 (1959η) magnetic data [*Cain et al.*, 1962] and the analysis of magnetic survey data [*Jensen and Cain*, 1962], was made in connection with preparation for analysis of the magnetic data to be obtained with the polar orbiting geophysical observatory [*Ludwig*, 1963].

The need for a general system of rapid illustration in geomagnetism has arisen with the advent of methods allowing automatic processing of large quantities of data. The techniques have been found of value not only for illustrating the results themselves but also in investigating the various steps of analyses.

Contouring procedure. The procedure followed [*Bedient and Neilon*, 1962] is first to produce coarse grid point values of the function to be contoured and then to perform a two-dimensional quadratic interpolation to locate the contour lines on a much finer grid. In the application illustrated here the original field is computed on a ½-inch grid 39 units in latitude and 55 units in longitude, a total of 2145 points. The interpolation is then performed by means of Bessel's central difference interpolation formula (second degree) to produce a further division of this interval by a factor of 8 so that the 'decision field' is a two-dimensional 1/16-inch grid. The decision field is analyzed, and the plotter pen instructions are generated on a 1/8-inch square grid for drawing contours between the 'high' and 'low' points in the field. The available variable control features include the selection of a particular contour and the contour interval to be used. The contour programs include sufficient corrections to compensate for the dynamics of the plotter system with a specified electronic filter network.

1960.0 magnetic field. The magnetic field illustrated here is that computed by *Jensen and Cain* [1962] for the epoch of 1960.0 using a selected set of 7400 magnetic field observations for the period 1940–1961. Figures 1, 2, 3, and 4 represent the contours of F, H, Z, and I, respectively, from this 48-term spherical harmonic expansion. (The map projection is a modification of the Miller Cylindrical [*Miller*, 1942] as published by Army Map Service.) The three-digit numbers printed in the open areas are the highs and lows in the fields positioned approximately at the decimal point of the numbers. The large-scale kinks that usually appear in manually contoured magnetic maps are significantly absent from these four figures. However, there are slight waves in a few of the lines, owing to the 1/8-inch grid spacing and to the dynamics of the plotting system. These small irregularities vary for different plotting equipment. Tests have shown that, on the map scales illustrated, the contours are accurate to about ±1° of latitude. The pen speed for this system is about 20 cm/sec, so that the average plotting time is of the order of 3 minutes for each map.

To compare this relatively smoothed version

[1] Presented at the 44th Annual Meeting of the AGU in Washington, D. C., April 23, 1963.

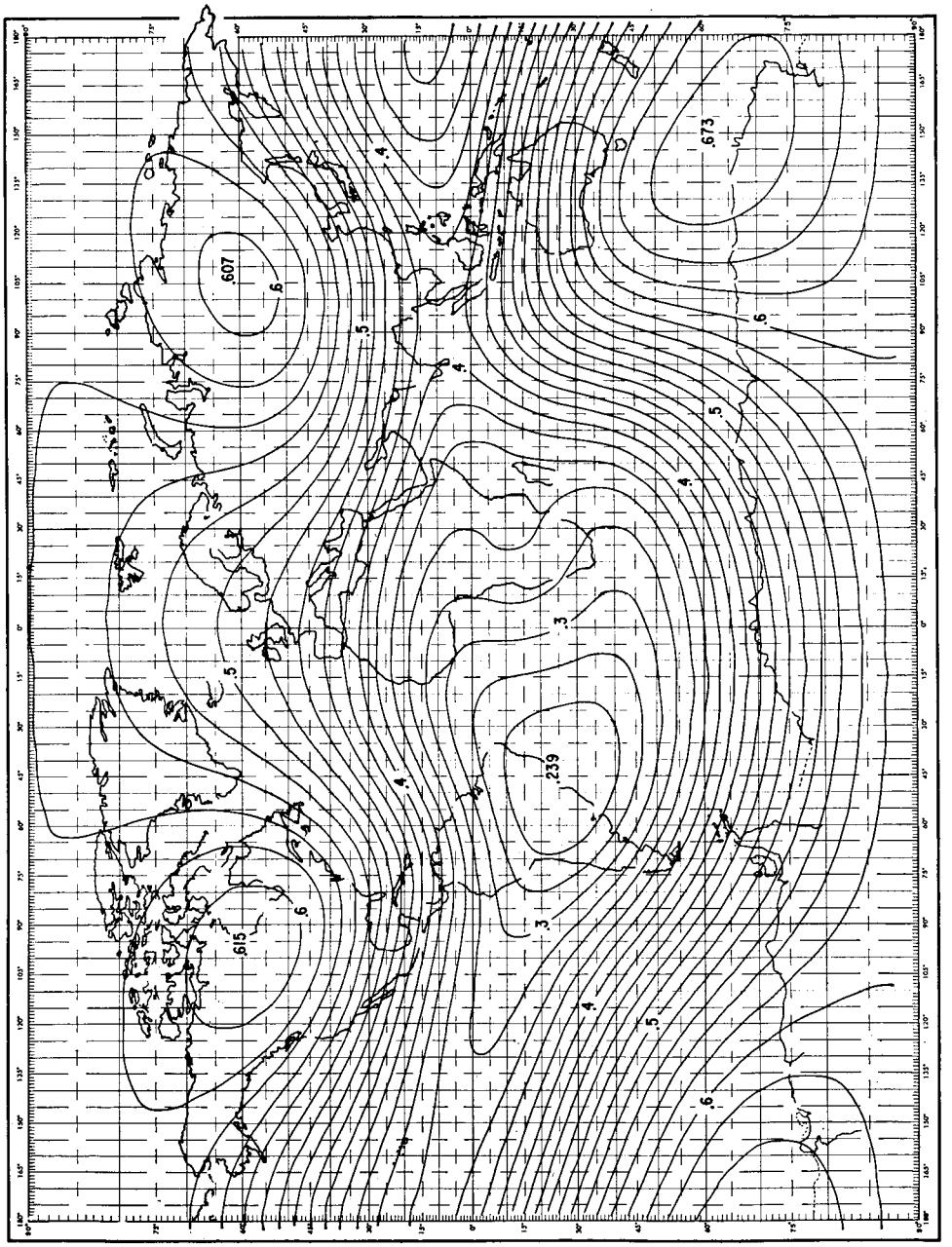

Fig. 1. Contours of the total intensity of the geomagnetic field in gauss, synthesized from a set of 48 spherical harmonic coefficients [*Jensen and Cain*, 1962] for epoch of 1960.0 (contour interval 0.02 gauss). All centers are highs except the 0.239 over South America.

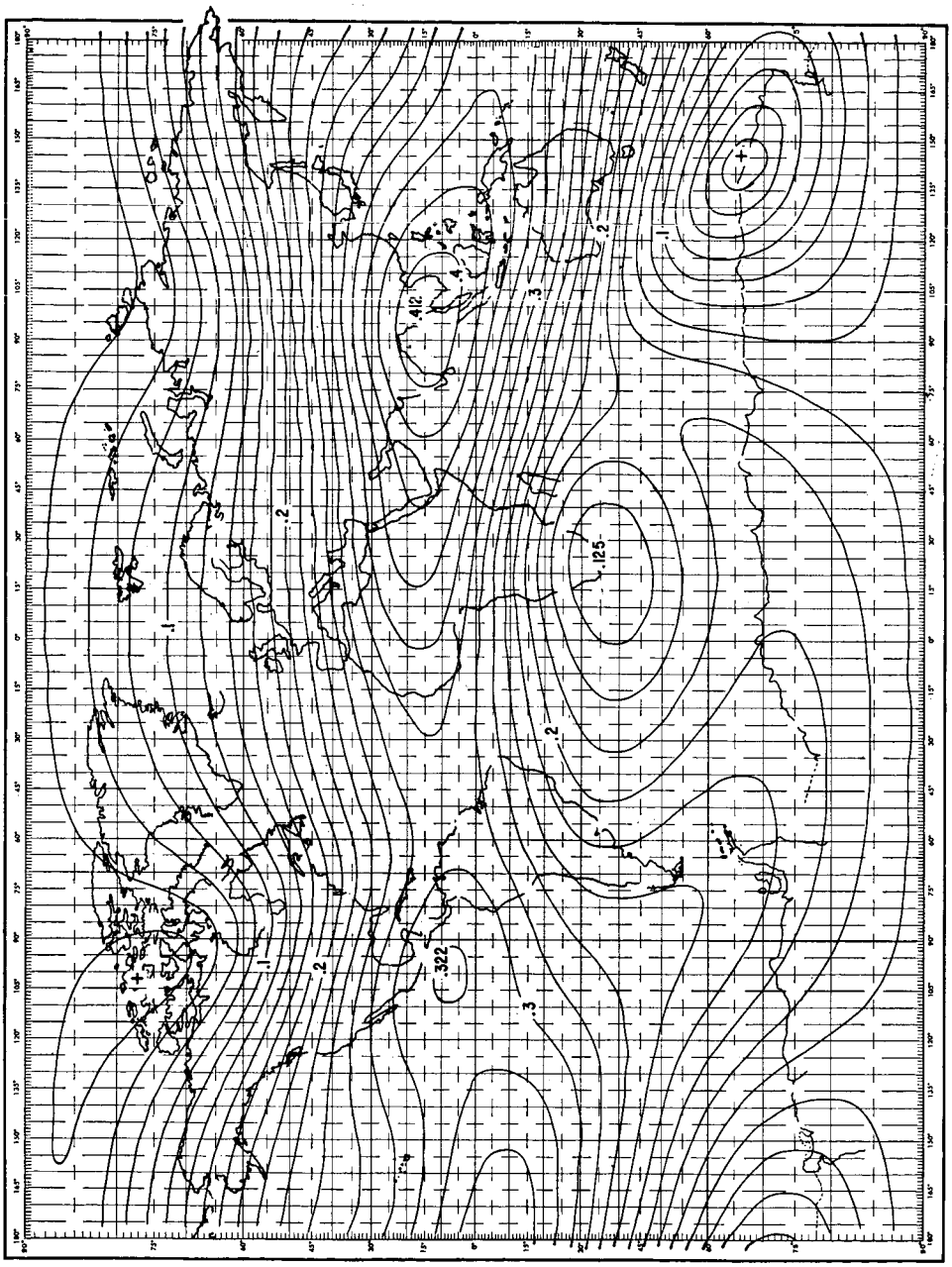

Fig. 2. Contours of horizontal intensity from same spherical harmonic expansion as Figure 1 (contour interval 0.02 gauss). The plus signs are the positions of the north and south geomagnetic poles using this expansion. The two centers near the equator are highs; the center near the tip of South Africa is a low.

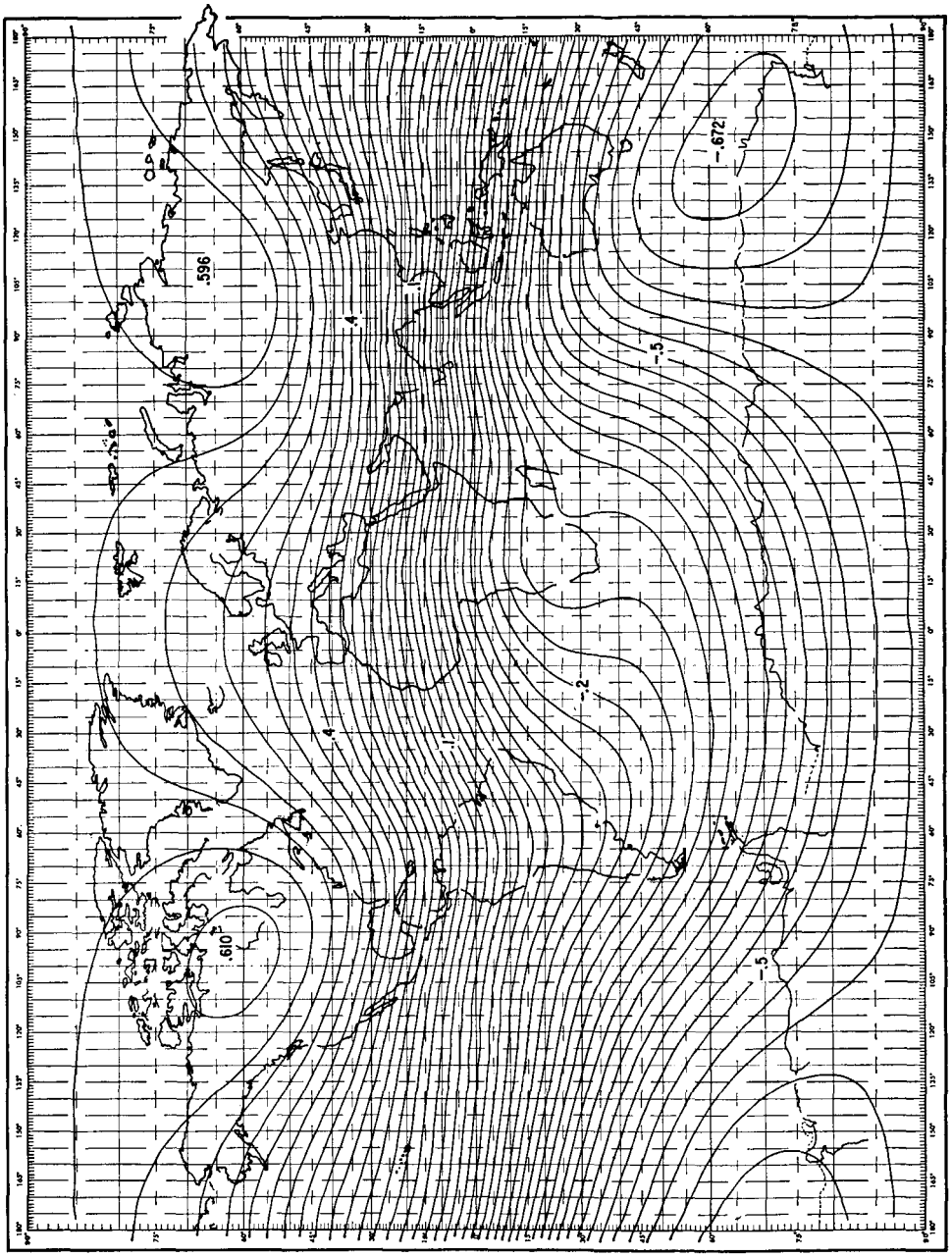

Fig. 3. Contours of vertical intensity from the same spherical harmonic expansion as Figure 1 (contour interval 0.03 gauss). Positive highs appear in Canada and Russia, and a negative high in Antarctica.

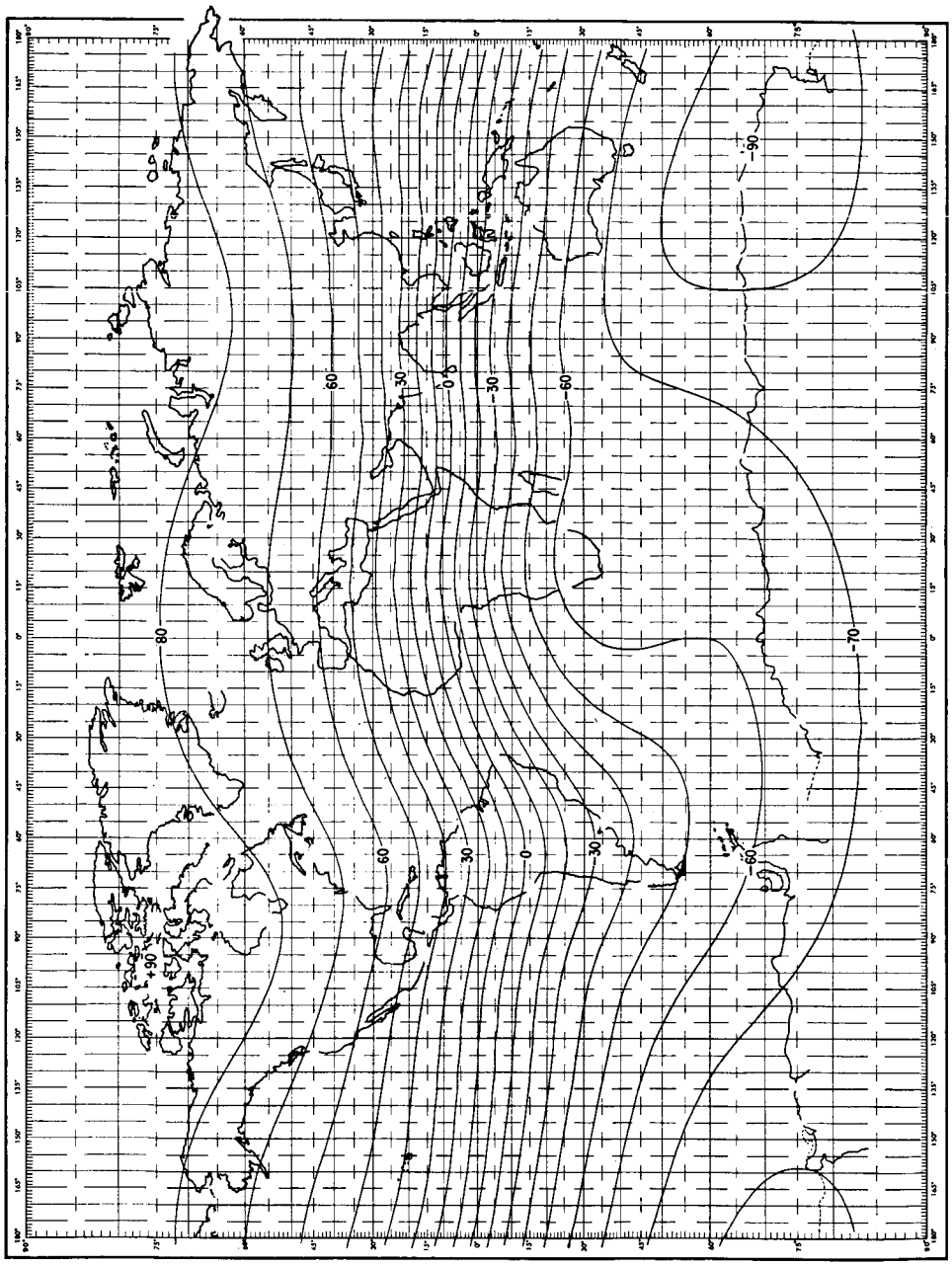

Fig. 4. Contours of inclination from same spherical harmonic expansion as Figure 1 (contour interval 10°).

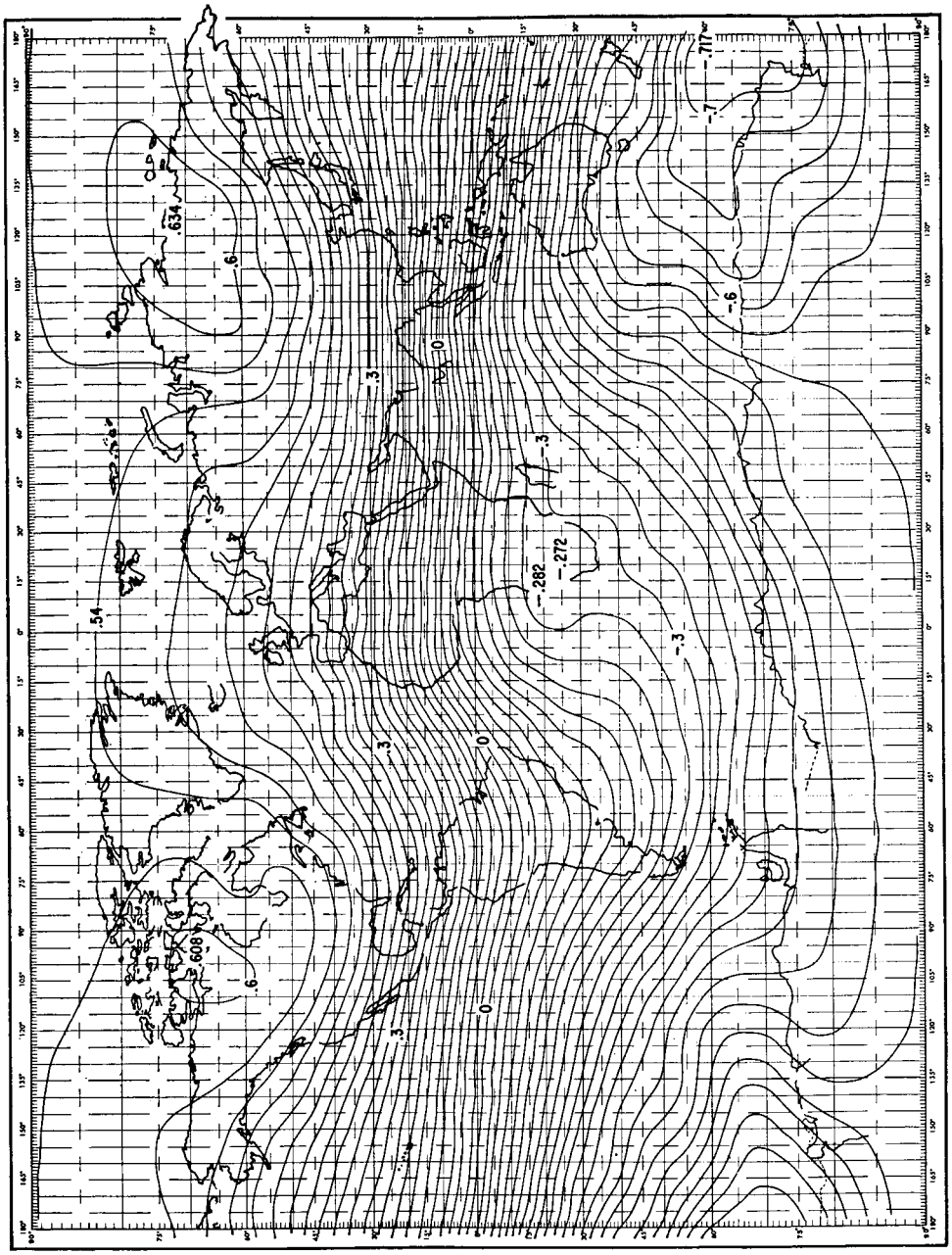

Fig. 5. Contours of vertical intensity synthesized from the set of 512 spherical harmonic coefficients [*Jensen and Whitaker*, 1960] for epoch 1955.0 (contour interval 0.03 gauss). Major highs in Canada, Russia, and Antarctica are nearly the same as those in Figure 3. In addition, a −0.282-gauss high and a −0.272 low appear in Africa.

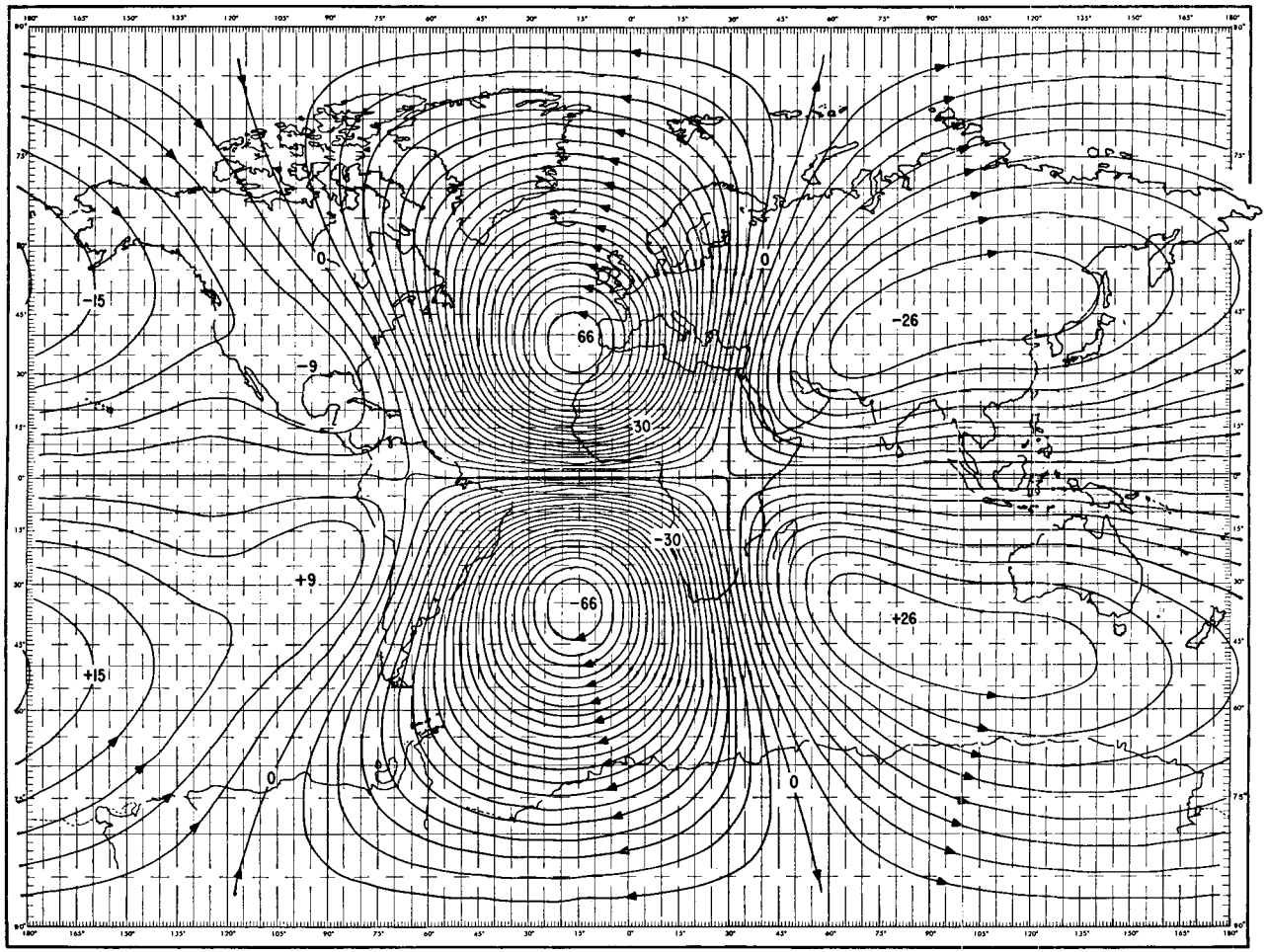

Fig. 6. Model S_q ionospheric current system with the sun on the Greenwich meridian (1200 UT). Values of current flow are in kiloamperes with a contour interval of 3000 amp. The current flows in the direction of the arrows with no current flowing across the equator. The spherical harmonic expansion is taken from *Chapman and Bartels* [1940] for the mean equinox of 1902, assuming a current height of 100 km.

of the field with a more complex map, in Figure 5 the Z-component contours have been plotted from the 512-term expansion of *Jensen and Whitaker* [1960]. Comparing the chart of this higher-order expansion with Figure 3 shows that it is possible with this plotting system to illustrate much more detail than that contained in a 48-term expansion. That Figure 5 is not as detailed as the original 1955 Z charts (USN Hydrographic Office), from which the data for the original analysis were taken, is due primarily to the fact that this analysis utilized data at only 10° intervals in latitude and longitude. This additional smoothing could not have occurred in the contouring, since the plotting system utilized a grid of 2145 points, whereas the original analysis by Jensen and Whitaker only employed approximately 614 observed values of Z. With this particular grid system it should be possible to represent spherical harmonic expansions of the field containing more than the 512 coefficients used. Of course, the possible map detail is limited only by the input data and scale of the map being used, so that any degree of detail can be represented by suitably expanding the scale and plotting the map by sections.

Magnetic variations. This technique of automatic plotting has also been investigated for the illustration of the time variations in the field as well as the main field itself. This application is illustrated here only by the representation of the quiet solar daily variations S_q. Figure 6 plots an idealized ionospheric current system computed by M. Sugiura (private communication) from a set of harmonic coefficients [*Chapman and Bartels,* 1940] representing the averaged quiet field variations at the equinoxes. Although this particular representation was produced from analytic functions, it is likely that the system will be adaptable to the illustration of worldwide magnetic variations on a synoptic basis either by representative ionospheric current stream functions or simply by contouring changes in specific components as abstracted from magnetic variometer records.

Acknowledgment. We wish to acknowledge the able assistance of S. Hendricks in preparing the diagrams.

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(Manuscript received June 3, 1963.)