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Horizontal Polarization in Array Studies of Anomalous Geomagnetic Variations

RECENTLY, natural external variations of the geomagnetic field have been used extensively to study the electromagnetic response of the Earth and thus to estimate its electrical conductivity structure. In particular magnetic storms and bays, having power mostly in the frequency range 0.5 to 10 cycles/h, are suitable for examination of the crust and upper mantle.

Studies of such variations[1] have revealed that the Earth has a highly heterogeneous conductivity above a depth of about 400 km. One particular phenomenon is that of "coast effect" anomalies, first observed by Parkinson[2] and since recognized at many ocean edges throughout the world. These have their origin in the lateral conductivity contrast of the continental crust and mantle with that of the highly conductive deep oceans, and possibly also that of the conducting mantle beneath the oceans. The "coast effect" is characterized by large vertical variations near the ocean edge, which tend to correlate with horizontal variations perpendicular to the coast line.

In 1971 we conducted a study of magnetic variations recorded simultaneously at 26 stations across SE Australia (Fig. 1). The survey area is bounded on the SW and on the East by two mutually perpendicular ocean edges, thus allowing a study of the "coast effect" in two dimensions. The basic techniques of analysis of such array studies are well established[3] and results for the Australian coastal experiment are being presented elsewhere[4]. The purpose of this letter is to demonstrate, by reference to the "coast effect" anomalies observed, how the polarization of the horizontal field can aid interpretation of the amplitude and phase maps obtained in array studies.

Standard Fourier transformation of simple magnetic variations enables the mapping of the amplitude and phase components of the variation across the array, at different frequencies. Careful selection of the data interval enables the computation of a complete, unique frequency spectrum for a single

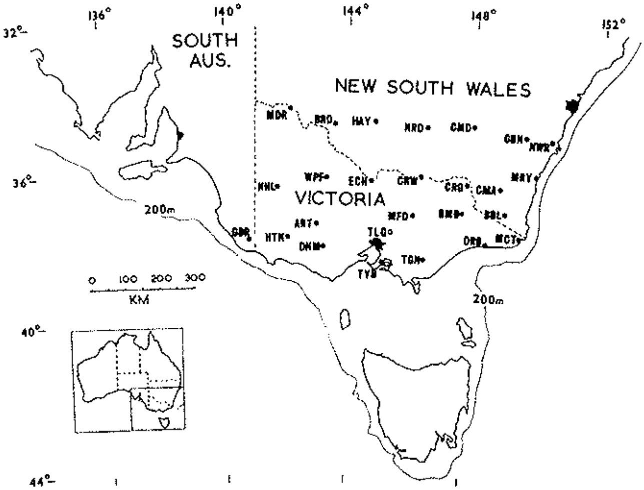

Fig. 1 Map of observing sites.

transient variation, unaffected by other variations of different polarity which occur at different times. The horizontal polarization at any frequency can then be calculated using the standard monochromatic equations[5]. In general the horizontal field is elliptically polarized. The magnetic field vectors along major and minor axes have an amplitude ratio given by the eccentricity of the ellipse, and differ in phase by 90°.

We found that, in SE Australia, the relative amplitude of the vertical variation field near the ocean edges is closely related to the horizontal field polarization, being largest when the major axis of the ellipse is oriented perpendicular to the ocean edge. Fig. 2*a* shows an example of the amplitude and phase maps of the true North (X), East (Y), and downwards vertical (Z) components of a magnetic bay at period 85.3 min. The polarization ellipse in Fig. 2*a* is such that the major axis is approximately perpendicular to the SW ocean edge and the minor axis is perpendicular to the East coast. The amplitude of the vertical (Z) response at the SW coast is correspondingly larger than that at the East coast, and the lineament of the Z amplitude contour lines, parallel to both coast lines, is very clear.

The phase variation of the Z response across the array is approximately 26 min, far greater than that of either the X or Y components. The reason for this is clearly seen in Fig. 2*b* where the horizontal field maps have been plotted again, now resolved along the major and minor axes, Y′ and X′ respectively, of the polarization ellipse. The change in phase of the minor axis (X′) component is a result of small

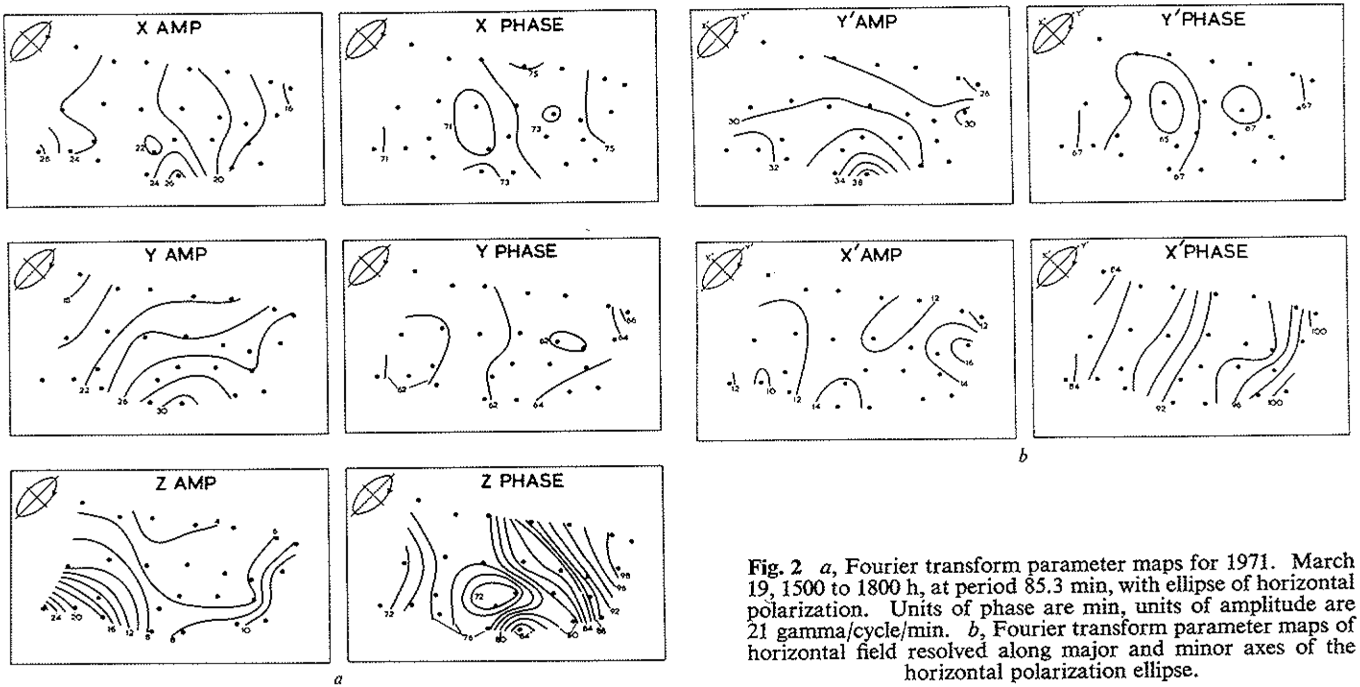

Fig. 2 *a*, Fourier transform parameter maps for 1971. March 19, 1500 to 1800 h, at period 85.3 min, with ellipse of horizontal polarization. Units of phase are min, units of amplitude are 21 gamma/cycle/min. *b*, Fourier transform parameter maps of horizontal field resolved along major and minor axes of the horizontal polarization ellipse.

changes in the polarization ellipse across the array; the ellipse shown was calculated as a mean of those from several stations in the centre of the area, and there the X′ phase does lead the Y′ phase by about 20 min ($\frac{1}{4}$ cycle), as expected.

The phase of Z on the East coast (90 to 98 min), is close to that of the X′ component (98 to 100 min), but at the SW coast line the phase of Z (72 to 76 min) is closer to the phase of Y′ (about 67 min) than that of X′ (84 to 88 min). The complex phase structure of Z in the central Southern part of the array represents a region where the Z component is changing from correlation with the positive X′ component to correlation with the positive Y′ component.

The Z maps can therefore be explained qualitatively at both coast lines as showing approximately in phase correlation with that component of the horizontal field which is perpendicular to the ocean edge and positive in the direction ocean to land.

This example demonstrates how, in the case of coast effect anomalies, the complicated vertical amplitude and phase maps obtained in geomagnetic array studies can be understood more fully by recourse to the horizontal field polarization, as calculated on a monochromatic wave basis. Because many continental conductivity anomalies also show linear trends we believe that mapping the horizontal field variations resolved along the major and minor axes of the horizontal polarization ellipse will aid in the interpretation of a wide range of electrical conductivity structures.

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