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Magnetotellurics with a remote magnetic reference

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Magnetotelluric measurements were performed simultaneously at two sites 4.8 km apart near Hollister, California. SQUID magnetometers were used to measure fluctuations in two orthogonal horizontal components of the magnetic field. The data obtained at each site were analyzed using the magnetic fields at the other site as a remote reference. In this technique, one multiplies the equations relating the Fourier components of the electric and magnetic fields by a component of magnetic field from the remote reference. By averaging the various crossproducts, estimates of the impedance tensor not biased by noise are obtained, provided there are no correlations between the noises in the remote channels and noises in the local channels. For some data, conventional methods of analysis yielded estimates of apparent resistivities that were biased by noise by as much as two orders of magnitude. Nevertheless, estimates of the apparent resistivity obtained from these same data, using the remote reference technique, were consistent with apparent resistivities calculated from relatively noise-free data at adjacent periods. The estimated standard deviation for periods shorter than 3 sec was less than 5 percent, and for 87 percent of the data, was less than 2 percent. Where data bands overlapped between periods of 0.33 sec and 1 sec, the average discrepancy between the apparent resistivities was 1.8 percent.

INTRODUCTION

In the magnetotelluric (MT) method, one seeks the elements of the impedance tensor $Z(\omega)$ from the equations

$$E_x(\omega) = Z_{xx}(\omega)H_x(\omega) + Z_{xy}(\omega)H_y(\omega), \quad (1)$$

and

$$E_y(\omega) = Z_{yx}(\omega)H_x(\omega) + Z_{yy}(\omega)H_y(\omega). \quad (2)$$

In equations (1) and (2), $H_x(\omega)$, $H_y(\omega)$, $E_x(\omega)$, and $E_y(\omega)$ are the Fourier transforms of the fluctuating horizontal magnetic (H) and electric (E) fields $H_x(t)$, $H_y(t)$, $E_x(t)$, and $E_y(t)$. If one multiplies equations (1) and (2) in turn by the complex conjugate of each of the frequency-dependent fields, and averages the resulting autopowers and crosspowers of the fields over many sets of data, one obtains eight simultaneous equations that can be solved for the impedance elements. As is well known, the autopowers may severely bias the impedance estimates if there is noise in the measured fields (Sims et al, 1971; Kao and Rankin, 1977). An earlier paper (Goubau et al, 1978) discussed two different approaches to reducing this bias, namely, (1) a solution of the eight simultaneous equations for the impedance elements in terms of crosspowers alone, and (2) a solution of the equations in terms of weighted crosspowers. Analysis techniques for MT measurements with a fifth (electric or magnetic) local reference channel were also discussed, including a crosspower analysis in which one multiplies equations (1) and (2) by the complex conjugate of the Fourier transform of the reference field. It was concluded that any of the 4- or 5-channel methods would work satisfactorily provided that the noise in the various channels was uncorrelated. These techniques were tested on data obtained at Grass Valley, Nevada. In most measurements, there was a significant level of correlated noise found between some channels. Most techniques yielded apparent resistivities that were biased.

Finally, use of a remote magnetometer was proposed to obtain reference fields $H_{xr}(t)$ and $H_{yr}(t)$ in which the noise should be uncorrelated with any of the

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